Elaho River Hydroelectric Development

Engineering Overview Study

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ELAHO RIVER HYDROELECTRIC DEVELOPMENT

ENGINEERING OVERVIEW STUDY

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SYNOPSIS

SYNOPSIS

The Elaho River could be utilized to produce hydroelectric energy by diverting it to a powerhouse at Deserted Bay on Jervis Inlet or by a dam and powerhouse on the Elaho River.

The Deserted Bay Alternative would consist of a 145-m high earthfill dam on the Elaho River 6 km upstream of its confluence with the Squamish River, a 14.5-km long power tunnel diverting water to a two-unit surface powerhouse in the Deserted River valley, and a 3-km tailrace channel discharging water into Deserted Bay on Jervis Inlet.

The Elaho River Alternative would consist of a similar dam at the same location as the Deserted Bay Alternative but with a 2.6-km long power tunnel through the right abutment conveying water to a two-unit surface powerhouse on the Elaho River.

Capacity, water supply, energy and cost data are tabulated below. Costs do not include transmission.

	Deserted Bay	Elaho River
Number of Units	2	2
Generating Capacity (MW)	340	200
Average Power Flow (m^3/s)	83.5	89.8
Average Head (m)	300	132
Average Annual Energy (Av. MW)	224	108
(GW.h)	1,962	945
Construction Cost ($ Million) (Oct. '82 Prices)	661	468
Unit Energy Cost ($/Av. kW)	2,951	4,333

The Deserted Bay Alternative would produce energy at a unit cost comparable to projects being considered for future additions. In addition to its prime function to generate electric power, it would reduce Elaho floods and could provide significant flood control benefits to the

Squamish valley. It would, however, encroach on Indian Reserve No. 15 at Deserted Bay (I.R.15). I.R.15 could be avoided but at additional cost.

The Elaho River Alternative would have a significantly higher unit energy cost than other projects and would offer somewhat smaller potential flood control benefits than the Deserted Bay Alternative.

Because of the attractive unit cost of energy, it is recommended that consideration be given to proceeding with feasibility studies for the Deserted Bay Alternative and the alternative avoiding I.R.15. It is also recommended that feasibility studies for the Elaho River Alternative be considered only if both diversion alternatives are found to be unacceptable or infeasible.

SECTION 1.0 - INTRODUCTION

1.1 Background

The first known studies of the hydroelectric development of the Elaho River were performed circa 1940 for the Water Rights Branch of the Department of Lands, B.C. They were described in a report by E. H. Tredcroft[1]. Two diversion alternatives were suggested; both involved tunnels to Princess Louisa Inlet, one from a pondage to be formed on the west fork known as Sims Creek and the other from a reservoir to be created by a dam on the main stem of the Elaho.

Between 1955 and 1957, the B.C. Engineering Co. Ltd. carried out field and office investigations of the reservoir alternative for the B.C. Electric Co. Ltd[2,3]. The investigations included flow measurement, two boreholes, a geological appraisal and the preparation of schematic layouts and cost estimates for a range of capacities. Eight possible damsites were studied in the Elaho valley. The two exploratory boreholes revealed unfavourable foundation conditions at the most upstream site and attention concentrated on sites further downstream. Sites designated 6 and 7, near the head of the gorge leading to the Squamish valley, were considered to be the most promising. Site 6 was deemed worthy of first investigation because it was believed that it would yield the lowest construction cost. However, site 7 was used for the cost estimates to give conservative figures.

A further study of the Elaho River was performed as part of the 1972 Provincial Power Study for the British Columbia Energy Board[4]. The study proposed a 90 m high storage dam at site 6 and a 14.5 km unlined power tunnel to a powerhouse adjacent to the Deserted River at Deserted Bay on Jervis Inlet. With a maximum net head of 290 m and a tunnel capacity of 198 m^3/s, the 500 MW project would have

produced an average annual energy output of 1,710 GW.h (195 MW average). This project configuration was used as the basis for the cost update and environmental review performed by Hydroelectric Design Division (HDD) as part of the Hydro Alternative Review Program (HARP) in 1976[5]. The average annual energy output was then estimated to be 1,730 GW.h.

1.2 Terms of Reference

Engineering Assignment No. 482-084, dated 7 July 1982, authorized the Hydroelectric Generation Projects Division (HGPD) to provide engineering services for the present overview study of the Elaho Project.

The Assignment required HGPD to:

1. Examine alternatives, including:

   (a) a diversion scheme with a dam on the Elaho River and a power tunnel diverting water to a powerhouse on the Jervis Inlet, but maintaining the potential for flow releases to the Squamish River,

   (b) a non-diversion scheme with a dam and powerhouse on the Elaho River.

2. Investigate the flood control effect of each scheme on the Squamish Estuary.

1.3 Scope of Work

The objective of the overview study was to determine whether the Elaho Project justified more detailed feasibility studies and investigations. The study was based on available information supplemented by field reconnaissance. In addition, a simple line-traverse survey was run in the lower reaches of the Elaho River to

reconcile a substantial discrepancy between the contours shown on maps from different sources for that section of the river and in the vicinity of its confluence with the Squamish River.

In addition to the two schemes specified in the Assignment, alternatives were studied for a third scheme which would divert water to a powerhouse on the Squamish River. The preferred alternatives, for which layouts were prepared, were selected after approximately optimizing the live storage, dam height and tunnel capacity for each alternative using preliminary, order-of-magnitude cost estimates for the major project components. Layouts were prepared taking the general circumstances of the site into consideration but no detailed optimization of individual features or arrangements was performed.

SECTION 2.0 - PROJECT AREA

2.1 Location and Physiography

The project area is located in the Pacific Range of the southern coastal mountains approximately 110 km north-north-west of Vancouver. It extends from the Jervis Inlet in the west to the Squamish River in the east. To the north, it is bounded by the divide into Meager Creek and the Lillooet River and to the south by the valley of Ashlu Creek (Fig. 2-1).

The area was subjected to continental glaciation during the Pleistocene and is generally rugged. It is characterized by steep coastlines, fiords, hanging valleys, deeply incised river gorges and by glaciated mountains with peaks rising to over 2,600 m.

The Elaho River flows south for 30 km from its source at the Elaho Glacier and then south-south-east and south-east for 20 km to its confluence with the Squamish River, 50 km upstream of the town of Squamish at the head of Howe Sound. With the exception of the last 10 km, the Elaho valley is a broad hanging valley through which the river meanders with a gentle gradient. Since glaciation the land has rebounded causing stream rejuvenation, and active downcutting by the river in its lower reaches has created a steep gorge which connects to the deeper Squamish valley. The river has two major tributaries, Clendenning Creek and Sims Creek. Both originate in glacial cirques and flow south-easterly to join the Elaho during its southerly course.

In the south-west of the area, the Deserted River flows into Deserted Bay on Jervis Inlet. The valley of the Deserted River is a broad, partially drowned, hanging valley. The valley has a swampy nature caused by the presence of extensive beaver dams.

2.2 Access

The Elaho valley and the valley of Ashlu Creek are accessible by road from Vancouver.

The left bank of the downstream reaches of the Elaho River is accessible by a dirt road from a partially-gravelled dirt road on the left bank of the upper Squamish River. The latter road is an extension of the access road from Cheekye Substation to the Cheakamus powerhouse which connects with Highway 99 from Squamish and Vancouver. The junction of the Elaho and Squamish River roads is just upstream of the confluence and the Elaho road crosses the Squamish River on a timber bridge. There is also a dirt road on the right bank of the Elaho River in its lower reaches but the bridge which gave access to it has been removed.

A logging road also extends north-westerly up the valley of Ashlu Creek from the Cheakamus powerhouse access road. The road crosses the Squamish River on a timber bridge and extends to within 5 km of a logging road in the Deserted River valley.

The Deserted River road leads from a pier and logging facility on the shore of Jervis Inlet south of Deserted Bay. At present, access to the road, the shore of Jervis Inlet and to Princess Louisa Inlet is by sea from the Strait of Georgia via the Malaspina Channel.

Access to most of the area inland between the shores of Jervis Inlet and Princess Louisa Inlet and the Elaho valley can be gained at present only by helicopter. The nearest helicopter base is at Whistler resort, 55 km east of Deserted Bay.

2.3 Existing Development

The Elaho valley is undeveloped and the only habitation in the immediate vicinity is a logging camp at the confluence of the Elaho and Squamish Rivers.

There are three Indian Reserves on the shores of Jervis Inlet. I.R.15, belonging to the Sechelt Indian Band, is by far the largest of these reserves. It occupies 340 ha at the mouth of the Deserted River in Deserted Bay and along the shore of the inlet. The reserve contains the Native Environmental School, a teaching and dormitory facility providing a program of native environmental studies to Native Indian and non-Indian secondary students. The program is jointly sponsored by the Sechelt Indian Band and School District No. 46.

A religious retreat is located at Malibu on the north-western shore of the narrows at the entrance to Princess Louisa Inlet. At the head of the inlet is the Princess Louisa Provincial Park which contains a park office and residence.

2.4 Regional Geology and Seismicity

Fig. 2-2 shows a geological map of the project area.

(a) Surficial Geology

Overburden deposits are scarce in the project area and, except for valley floor deposits, those which do occur are generally shallow. Glaciofluvial valley deposits make up the majority of unconsolidated material in the area. The Elaho, Squamish and Deserted River valleys all contain glacial outwash material. The bedrock bottoms of hanging valleys such as the Elaho are usually irregular and often have reverse grades due to local

deepening by glacial erosion. The upper Elaho valley is filled with glacial outwash to depths possibly exceeding 100 m. A few terrace deposits are present in river valleys but silts and clay-size fractions are sparse.

The rugged mountainous terrain above El. 1500 is generally bare rock with occasional talus slopes. Large rockslides can be seen throughout the area. Glacier-fed streams with steep gradients carry large angular rock fragments to the valley floors and fans of angular material occur at the mouths of many tributary streams.

(b) Bedrock Geology

Large batholiths of the Coast Plutonic Complex form the majority of the bedrock in the project area. These intrusives have been identified as quartz diorite, granodiorite and diorite. They are granitic in texture, medium to coarse grained and very hard and competent. They often show foliations, mostly characterized by a sub-alignment of darker (mafic) minerals. The age of these intrusives is probably Jurassic to Cretaceous. They are often cross cut by andesitic dykes up to 2 m thick.

Metasedimentary rocks of the Lower Cretaceous Gambier Group are exposed along the shores of Jervis Inlet. Where examined in the Deserted River valley, Gambier rocks included: black argillite, mudstone, conglomerate with mudstone matrix, and fine sandstone. These rocks show extensive surface weathering and numerous defects but generally appear to be reasonably competent. The original bedding can be recognized in places. Argillites and phyllites have well developed foliations.

Gneissic roof pendants are also exposed in the area. Roof pendants are metamorphosed remnants of the rocks (generally marine sediments) that were present before intrusion of the coast batholiths. In plan, they are generally elongate in shape along a north-westerly axis. In section, pendants are typically wedges of rock that may extend to considerable depths. Rock types observed include gneisses, schists, migmatites, quartzites and various dyke rocks. These rock types are generally hard and competent except along weak, highly schistose, horizons.

Recent volcanics, in the form of basalt flows from an undetermined source nearby, are present at high elevations on the east side of the Elaho Valley. Mt. Cayley, which was an eruptive centre, is located 7 km east of the Elaho-Squamish confluence.

Geologic structure in the project area is greatly influenced by the massive nature of the plutonic rocks. Although the area has not been geologically mapped in detail, general comments can be made on structural features based on published sources, air photo examination and limited mapping.

The area displays regional tectonic lineations that generally follow distinct orientations. Major trends of lineations in the project area are 040° and 130°. For example, features such as Queens Reach of Jervis Inlet and the lower 10 km of the Elaho River are structurally controlled and trend 130° while the infilled valley of Deserted River, Princess Louisa Inlet and many streams trend 040°.

Plutonic rocks exhibit a rectilinear pattern of joints which are widely spaced. Along major joint orientations preferential erosion by ice and water has produced the valley topography. Numerous minor faults are anticipated throughout the region and

will likely be accompanied by alteration and brecciation in limited zones. In places, major scarps more than 100 m high have been identified on air photos. These scarps are possible evidence of past rock slides along jointing. The west wall of the Elaho River valley is a dip slope controlled by a set of steep, easterly dipping joints.

Contacts between roof pendants and batholiths are expected to be tight. A major regional fault trending north-west from Ashlu Creek forms the contact between the batholithic rocks and the Gambier Group rocks exposed along the shore of Jervis Inlet.

Rock of the Gambier Group appears to be closely jointed in some locations. The overall rock quality appears to be good.

The Recent volcanics were not inspected on the ground but they appear to be flows with steep faced outcrops forming major cliffs.

(c) Seismicity

According to the National Building Code (NBC) zoning map, the project is in seismic Zone 3. The minimum peak horizontal acceleration in Zone 3 is 6 percent of gravity and the maximum is not defined. The most severe earthquake in the seismic history of Western Canada occurred on 23 June 1946 on Vancouver Island (49.8°N; 125.3°W) about 135 km from the project site. Based on the Pacific Geoscience Centre (PGC) acceleration attenuation relationship, the computed peak horizontal acceleration from this event would have been 6 percent of gravity at the project site.

The major seismic source is the subducting plate in the Georgia Strait. This source is capable of generating a maximum earthquake of magnitude M7.5 according to previous studies[6]. It is estimated that the shortest distance from the subducting plate to the Elaho Project site is about 70 km. With such a magnitude and distance, the peak horizontal acceleration at the site could be about 20 percent of gravity and the peak velocity about 11 cm/s. Although the probability of occurrence of a magnitude M7.5 earthquake is extremely small, these values would be used in advance of more detailed seismic studies.

PRELIMINARY

SECTION 3.0 - DEVELOPMENT ALTERNATIVES

3.1 General

In accordance with the terms of reference, two mutually exclusive development schemes were considered, namely, diversion to tidewater in one of the inlets to the west of the Elaho valley and development within the Elaho valley (Fig. 3-1). A third development scheme was also considered, involving diversion to the Squamish River. Since such a scheme would not divert water out of the Elaho-Squamish basin, it would avoid several of the impacts associated with the tidewater diversions. In this respect it was generically similar to the in-valley scheme but offered possible economic improvements because of increased gross head.

Each scheme would involve a dam and reservoir. Previous studies had looked at a large number of possible damsites in the Elaho and Squamish valleys and concluded that the two most favourable sites were located in the gorge section of the Elaho valley approximately 7.5 km and 6 km upstream of the confluence with the Squamish River. Field reconnaissance as part of this overview study confirmed this conclusion and the two sites, known respectively as site 6 and site 7, formed the basis of the study of development alternatives. Studies commenced with a dam at site 6 but concluded with a dam at site 7. This change is discussed in Section 5.0.

The major alternatives considered are discussed below. For simplicity, where Elaho River and Squamish scheme alternatives were studied with a dam at each site, only the arrangement with the dam at site 7 is shown on Fig. 3-1.

3.2 Tidewater Diversion Scheme

Two alternatives were considered (Fig. 3-1).

The Princess Louisa Alternative would involve a power intake in the Elaho valley approximately 12 km upstream of damsite 7, and a 14-km tunnel diverting water to a surface powerhouse at Princess Louisa Inlet. The powerhouse would be located immediately to the southeast of the Provincial Park at the head of the inlet. The powerhouse site is remote and the terrain precipitous. The area is currently inaccessible by land. Narrows and rapids at the Malibu entrance to the inlet made sea access difficult except at slack high tide.

The Deserted Bay Alternative would involve a power intake approximately 3 km upstream of damsite 7 and a 14.5-km tunnel diverting water to a surface powerhouse in the Deserted River valley immediately upstream of Tsuahdi Creek. An open tailrace channel would be required to convey powerhouse discharges to Deserted Bay, a distance of 3 km. The tailrace channel would pass through I.R. 15.

A third alternative, with a 19-km power tunnel to the north of the Deserted River valley and a powerhouse on the shore of Jervis Inlet in the vicinity of Lot 894, was not pursued in detail because, although it would avoid I.R. 15, it would clearly have a higher unit energy cost than the Deserted Bay Alternative.

3.3 Elaho River Scheme

Four alternatives were considered (Fig. 3-1). The first two would involve at-site generation with a powerhouse located immediately downstream of damsite 6 and 7 respectively.

The third Elaho River Alternative would involve a tunnel and powerhouse on the right bank. The powerhouse would be located 2 km downstream of damsite 7.

The fourth Elaho River Alternative would involve a tunnel and powerhouse on the left bank. The powerhouse would be located at the 'S' bend in the river approximately 4 km downstream of damsite 7.

3.4 Squamish Scheme

Two alternatives were considered (Fig. 3-1).

The first Squamish Alternative would involve a 6.5-km tunnel diverting water from a dam at site 6 to a surface powerhouse on the right bank of the Squamish River 2 km upstream of the confluence with the Elaho. This arrangement proved less cost effective than Elaho alternatives which developed more head with shorter tunnels and consequently it was not investigated with a dam at site 7.

The second Squamish Alternative would involve a 12-km tunnel to an underground powerhouse on the right bank of the Squamish River 7 km downstream of the mouth of the Elaho.

SECTION 4.0 - HYDROLOGY

4.1 Streamflow Regime

The drainage area of the Elaho River is approximately 1250 km². The basin is situated in a transition zone between the wet coastal climate and the dry interior continental climate. Elevations within the basin range from 170 m to in excess of 2600 m. The terrain varies from sparse forest and logged sections at lower elevations to bare rock and extensive glaciers at higher elevations. Glaciers cover approximately 20 percent of the basin area.

a) Flows Available for Power

There are no streamflow gauges with long-term records in the basin but short-term records are available for two gauges (Fig. 4-1). The first gauge, No. 08GA041 (Elaho River near Squamish), was situated at damsite 6 and operated intermittently from 1955 to 1958. The second gauge, No. 08GA071 (Elaho River near the mouth), is located just above the confluence with the Squamish River and has operated since 1981. The gauges have drainage areas of 1140 and 1250 km² respectively.

The nearest long-term station, No. 08GA022 (Squamish River at Brackendale), has a drainage area of 2330 km² and continuous records from 1955. This and other WSC gauging stations which have operated or are operating in the vicinity of the Elaho basin are also shown on Figure 4-1.

Because of the lack of any long-term streamflow or meteorological data within the basin, synthetic monthly streamflow values had to be produced by proportioning data from outside

the basin. Monthly streamflow values were produced for both damsites for the period of 35 water years from 1941 to 1975. For the period from 1941 to 1967, the values developed for damsite 6 in the 1972 B.C. Energy Board study were used. These had been produced by extending the record of gauge No. 08GA041 (Elaho River near Squamish) by correlation with gauge No. 08GA017 (Cheakamus River at Garibaldi) and adjusting by the ratio of their respective drainage areas. A short break in the record of the gauge at Garibaldi had been made up by correlation with gauges No. 08GA043 (Cheakamus River at Brackendale) and No. 08MG005 (Lillooet River near Pemberton). In both cases, the Langbein method of correlation had been used. Flows for damsite 7 were obtained pro rata using the ratio of the drainage areas. For the period from 1968 to 1975, monthly streamflows for both damsites were obtained pro rata from the record of gauge No. 08GA022 (Squamish River at Brackendale) according to the ratio of their respective drainage areas. Values for the gauge were first adjusted by deducting the discharge from Cheakamus powerhouse. The mean annual flows obtained for damsites 6 and 7 were 86.9 m^3/s and 90.4 m^3/s respectively. The maximum and minimum monthly flows for the two damsites were 364.4 m^3/s and 7.0 m^3/s, and 379.1 m^3/s and 7.3 m^3/s respectively.

Because of its location in a climatic transition zone, the Elaho basin exhibits a flood discharge pattern combining characteristics from both continental and coastal basins. Spring snowmelt causes the highest sustained flows but fall rainstorms, particularly falling on snow pack, cause the peak flood discharges (Fig. 4-2). Although the discharges shown on the Flow Probability Curve are for the Squamish River at Brackendale, the pattern is considered indicative of the Elaho.

b) Diversion Design Flood

The flood with a 30-year return period was tentatively selected as the diversion design flood. Estimates of flood frequency at each damsite were obtained pro rata according to drainage area from the values obtained for the Squamish River at Brackendale using a log-normal distribution of the 30 years of recorded annual fall flood peaks (Fig. 4-2). The log-normal distribution gave the best fit of several tried . The diversion design floods for damsites 6 and 7 were estimated to be 1080 m^3/s and 1120 m^3/s respectively. These values agree with those derived in the B.C. Energy Board study.

c) Probable Maximum Flood

The original Probable Maximum Flood (PMF) estimate for damsite 6 was made for the B.C. Energy Board study. It used a statistical approach in which maximum envelope curves for the south coastal region were derived for the mean annual flood peak and the standard deviation of these annual flood peaks. The method involved adding the mean annual flood peak to a constant, k, times the standard deviation of these flood peaks. The estimated PMF value of 3400 m^3/s corresponded to a mean flood peak of 708 m^3/s plus ten standard deviations (10 x 269 m^3/s). Recent studies for the south coastal basins in British Columbia indicated that the use of ten standard deviations gave values which were unacceptably low. A recent estimate for this k value for the Cheakamus Project was found to be approximately 16.

In view of the variability of the statistical estimates, especially in the absence of long-term hydrometric records, it was recognized that an estimate based on basin modelling would be more valid. There is only one climatological station in the

basin, located at the stream gauge known as Elaho near the mouth in the lower-most part of the drainage basin, and this has only operated since 1981. Therefore, no meteorological study could be done to estimate the critical runoff-producing conditions such as the probable maximum precipitation, extreme snowpack and critical temperature sequences. As the use of a basin model was considered outside the scope of the overview study, the PMF results obtained in the south coastal region using basin modelling were plotted on log-log paper showing the 24-hour PMF against drainage area. This gave two envelope curves which defined the limits for south coastal PMFs.

The value for Elaho was judged taking into consideration the physical characteristics of the basin, particularly the percentage of glaciers as related to adjacent basins. The value adopted for the PMF at site 6 was 5000 m^3/s; this is larger in proportion to drainage area than the adjacent Cheakamus basin because the Elaho basin contains a considerably greater percentage of glacier. Once the peak daily value of 5000 m^3/s was determined, a hydrograph shape was derived using the 1981 Halloween storm hydrograph from the gauge Squamish at Brackendale. An adjustment for base flows was made using the gauge on the Elaho, and the remainder of the hydrograph was proportioned to equal a peak daily flow of 5000 m^3/s. It is expected that the final PMF obtained from detailed modelling will be similar to Cheakamus with the addition of a glacial component. The value of 5000 m^3/s should be an upper limit for site 6. For the purpose of the overview study, the PMF for site 7 was proportioned according to its drainage area.

The methods described above for estimating power flows and design floods are adequate for this level of study. However, the Elaho basin has very limited flow records and the hydrologic regime is complicated by glaciers and steep climatological gradients. If

studies are to be advanced to the feasibility level, a network of climatological and streamflow stations would be required in order to estimate power flows and design floods with confidence.

4.2 Sediment Regime

So far as is known, no measurements of suspended sediment or of bedload material have been made in the Elaho basin. Therefore, estimates of the sediment regime of this basin have had to be based on the fragmentary sources of available data. The Elaho basin is expected to have medium to high sediment yield and concentration for the following reasons:

1. Glaciers cover a significant proportion of the basin.

2. The basin is relatively wet with a moderate climate.

3. There has been logging activity within the basin with accompanying road development.

4. The river and tributaries flow at steep slopes for significant percentages of their lengths.

Creation of a reservoir on the Elaho would provide a trap for sediments carried by the river. Because the greatest proportion of glaciers within the Squamish system are located in the Elaho basin, it is likely that much of the sediment load is contributed by the Elaho. This glacial contribution would be largely trapped in the proposed reservoir and therefore the sediment regime of the lower Squamish River and its estuary would likely be significantly affected.

Estimates of sediment yield for this study were based on regression equations incorporating basin characteristics which were developed for highly glaciated basins in Alaska. These preliminary estimates were aimed at providing conservative upper limits for the basin. They have been used to compute a life for the proposed reservoir sites which is in excess of 500 years; the true sediment yield is probably significantly lower.

4.3 Ice Regime

Because of the lack of any long term streamgauging stations in the Elaho basin, there are no records to indicate the extent and duration of ice cover on the river. From a study of comparable basins it appears likely that the Elaho River is seldom completely frozen over.

With hydroelectric development of the Elaho River, the reservoir would probably remain ice covered from December or January to April or May, although the ice sheets would become fractured by the stresses induced by reservoir fluctuations. Upstream from the power intakes, there would be openings in the ice sheet caused by increased flow velocity.

It is likely that the river channels would remain ice-free for considerable distances downstream from the powerplants.

SECTION 5.0 - POWER AND ECONOMIC STUDIES

5.1 General

Power studies were performed to determine the firm energy and the long-term average energy production of each of the development alternatives discussed in Section 3.0. Firm energy is the average energy which the project could have produced during the overall coincident drought for the B.C. Hydro system, from October 1940 to April 1946. The long-term average energy is the average energy which the project could have produced during the 35-year period from October 1940 to September 1975.

In previous overview studies, projects were sized to obtain a capacity factor equal to the system load factor of 60 percent. In this study the results of the power studies were combined with cost estimates to determine the project which produced energy at the least unit cost.

5.2 Project Oriented Program (POP)

Energy production was determined using the computer program POP, "Project Oriented Program". POP consists of a series of interactive data, simulation and result-analysis programs. The model simulates the monthly operation of up to three reservoirs and powerhouses according to user-specified operating rules and constraints. The simulation program uses a technique known as Linear Programming (LP) to determine reservoir releases within the specified constraints for each monthly time step. A detailed description of the program and its use in project studies is contained in the POP User Manual[7].

5.3 Methodology

Three features were evaluated as to their effect on energy production. They were:

1. reservoir live storage volume,
2. normal maximum reservoir level,
3. tunnel hydraulic capacity and corresponding powerplant capacity.

The optimal values for these features were determined in two stages. In the first stage, the minimum reservoir level was kept constant and a wide range of combinations of live storage volumes, and hydraulic and generating capacities were simulated. The energy produced by each combination was multiplied by the unit energy values to obtain the annual power benefit. The annual cost of each combination was estimated using order-of-magnitude cost functions for the dam and tunnel. Annual costs were then deducted from annual benefits to determine the combination with the greatest net benefit, the economically optimal combination.

In the second stage, the live storage and the tunnel and generating capacity determined in the first stage were used with a range of normal maximum reservoir levels. Net benefits were calculated and the economically optimal normal maximum reservoir level was determined.

5.4 Assumptions and Criteria

1. Economic criteria used were those developed by System Engineering Division for 1983 (Tables 5-1 and 5-2).

2. Tunnel hydraulic characteristics were based on an evaluation of the general rock conditions. An approximate optimization of

the two tidewater diversion alternatives, which had the greatest gross head and longest tunnels, indicated that the economic size would produce a headloss of about 10 percent. Other tunnels were sized to produce the same velocity. Tunnels were assumed to have concrete inverts for ease of access.

3. A freeboard of 9 m above normal maximum reservoir level was assumed for earthfill dams.

4. An average efficiency was used which varied according to the hydraulic losses in each tunnel. Two generating units were assumed and operating rules were selected to avoid extended operation below 60 percent gate by one or both units.

5. Alternatives diverting water to tidewater or to the Squamish River below its confluence with the Elaho were assumed to release 5 percent of the long-term average flow of the Elaho River from the dam to maintain an acceptable aquatic habitat. Alternatives discharging back into the Elaho River or into the Squamish River above the confluence were assumed to have no release requirements other than through the turbines.

5.5 Results

The studies showed little difference between damsites 6 and 7. Whichever site was used with the various power facilities, the optimal live storage would be about 900 million m^3 and the normal maximum reservoir level would be about El. 360. Site 6 was studied first because comparison of order-of-magnitude cost estimates indicated it would be less costly for the reservoir levels proposed in previous reports. However, as the studies progressed, higher reservoir levels were indicated where the cost comparison was no longer conclusively in favour of site 6. In addition, there is an old buried river channel at site 6 of unknown depth. While it could

possibly prove to be shallow and have little impact on costs, it could be as deep as the present river channel, which would increase costs significantly. Consequently, site 7 was selected for the preparation of layouts because its characteristics are known and the estimate of its cost is more reliable.

For the tidewater diversion scheme, the studies showed that the optimal reservoir level, live storage and hydraulic capacity would be essentially the same for the Deserted Bay Alternative and the Princess Louisa Alternative. Both alternatives would produce energy at a lower unit cost than any of the alternatives for the Elaho River and Squamish Schemes. However, although the cost of major project structures would be essentially the same for both alternatives, since the Princess Louisa powerhouse would be located in precipitous terrain currently inaccessible by land, access and transmission costs would be substantially higher than at Deserted Bay. No advantage was perceived in either alternative over the other in terms of an improvement in environmental impacts. Therefore, the Deserted Bay Alternative was selected on the basis of least cost.

Of the developments confined to the Elaho and Squamish basins, the studies showed that the third Elaho River Alternative, with a powerhouse 2 km downstream of damsite 7, would produce energy at the lowest unit cost. However, the difference between its unit cost and that of the second Squamish Alternative, with a powerhouse about 7-km downstream of the confluence, would be very small. Although the comparison was based on preliminary data, detailed layouts were not prepared to enable a better comparison because it appeared that the unit energy cost of either of these alternatives would be well in excess of the current long-term value of energy.

SECTION 6.0 - FLOOD CONTROL

The dam on the Elaho River would regulate runoff from approximately 50 percent of the drainage area of the Squamish River upstream of the gauge 08GA022 (Squamish River at Brackendale) or approximately 30 percent of the drainage area of the Squamish basin. Development of the Elaho River would therefore reduce floods and could have a significant flood control effect on the lower reaches of the Squamish River.

The effect of project operation on the mean monthly discharge of the Elaho River at damsite 7 is illustrated by the monthly flow duration curves shown on Fig. 4-2. Data for these curves were obtained during the power studies. Operation of the Deserted Bay Alternative reduced the maximum mean monthly discharge to 100 m^3/s, 27 percent of the maximum of 368 m^3/s under natural conditions; spill occurred only 6 percent of the time. For the Elaho River Alternative, the maximum mean monthly discharge was reduced to 225 m^3/s, 61 percent of the maximum under natural conditions; spill occurred only 3 percent of the time.

To assess the effect of the live storage provided for power generation, a 3-day flood volume frequency plot was derived for site 7 by proportioning flood peaks recorded at the gauge at Brackendale (Fig. 4-2). The shape and area of the hydrograph were determined by assuming the October 1981 hydrograph shape as recorded at the gauge near the mouth of the Elaho to be typical of the storm runoff at the damsite. The initial reservoir levels required to provide sufficient storage to contain the 3-day flood volumes without exceeding the normal maximum level (El. 360) were also determined and they are shown on Fig. 4-2 opposite the 3-day volumes. These initial levels were compared with the monthly medial reservoir target levels to estimate for each month the return period of the 3-day flood volume which could be contained without exceeding the normal maximum level, assuming the target levels were achieved. The results are shown in Table 6-1. It can be seen that there is considerable storage

available from December through to July. However, as discussed in Section 4.0, peak flood discharges tend to occur in the fall and early winter when the reservoir would be at or near normal maximum level and little or no live storage would be available. It would be necessary to provide some surcharge storage above normal maximum reservoir level to regulate flood inflows during this period.

To investigate the amount of storage likely to be required to regulate fall floods, surcharges of 2 m and 4.5 m were studied. These values were chosen because in routing the PMF it was assumed that a 2 m surcharge would be permitted before the spillway gates were fully opened and data for a 4.5 m surcharge was available from the PMF studies. The constant reservoir outflow required to maintain the reservoir level within each of the surcharges was calculated for the 3-day volume of the 10, 20, 50 and 100-year floods. The return periods of each constant outflow and of the reduced flows at Squamish were also calculated. The results are shown in Table 6-2. It can be seen that if, for example, 405 m^3/s were released during the 100-year flood inflow to the reservoir, the remainder of the inflow could be stored in a 4.5 m surcharge. The constant outflow of 405 m^3/s corresponds to a daily flood peak with a return period of less than 2 years at site 7 and the 100-year event would be reduced at Squamish to a runoff volume event with a return period of 17 years. While the calculations were performed using volume balances rather than incremental routing, they do indicate that significant flood control could be realized at Squamish by providing 2 to 5 m of surcharge storage in the Elaho reservoir. The effect of the Deserted Bay Alternative would be greater than indicated because up to 125 m^3/s of any outflow could be released out of the basin.

SECTION 7.0 - DESERTED BAY ALTERNATIVE

7.1 Project Description

The proposed project would consist of a dam and reservoir on the Elaho River and a 14.5-km tunnel diverting water to a powerhouse situated in the Deserted River valley. A 3-km open tailrace channel would convey powerhouse discharges to Deserted Bay in Jervis Inlet (Figs. 7-1 and 7-2).

The damsite is accessible by logging road from Cheakamus powerhouse. Access to the Deserted River valley would be provided by extending and improving the logging road which extends up the valley of Ashlu Creek from the Cheakamus powerhouse access road. Access to the powerhouse and other facilities in the Deserted River valley would be provided by extending and improving existing logging roads.

At the proposed normal maximum reservoir level, El. 360, the reservoir would contain 1,763 million m^3 of water and have a surface area of 3,420 ha (Fig. 7-2). The maximum drawdown would be 28 m, providing 883 million m^3 of live storage (equivalent to 31 percent of the average annual flow). With a constant release to the Elaho River of 4.5 m^3/s (5 percent of the long-term average flow) to preserve aquatic habitat and a tunnel capacity of 125 m^3/s, the live storage would provide an average power flow of 83.5 m^3/s. This is 92 percent of the long-term average flow of the Elaho River based on synthesized historic flows for the period October 1940 to September 1975.

With a tailwater level at El. 9, the project would develop a maximum gross head of 351 m and produce an annual average of 1,962 GW.h or 224 average MW. The firm energy would be 172 MW. With a generating capacity of 340 MW, the capacity factor would be 66 percent.

7.2 Site Geology

The dam at site 7 would be located in the deeply-incised gorge section of the Elaho River valley, 6 km upstream of the river's confluence with the Squamish River. Bedrock slopes rise from river level to far above the proposed crest. The left abutment rises with an average slope of 35° to El. 365 after which the slope decreases to 20°. The right abutment is formed by a relatively steep 40° slope, subject to avalanches, and bedrock is exposed over an extensive area.

Bedrock at the damsite is sound quartz diorite with some migmatite and quartz gneiss at higher elevations on the right bank. The rock is hard and competent with poorly developed, near-vertical, foliation trending 130°. The rock mass is cross cut by numerous dark grey andesite dykes varying in thickness from 0.15 m to 0.5 m and trending 160° to 170°. Many of the right bank linear features were not examined because of the precipitous topography but their orientation suggests they are weathered dykes.

Joints are generally widely spaced and tight. The left bank slope is structurally controlled by joints dipping out of the slope at angles generally between 25° and 50°. There is no evidence of faulting in the riverbed. The offset in the river just downstream of the proposed dam axis trends similarly to nearby dykes and could indicate a zone of weak rock such as a dyke (or dykes) accompanied by closely-spaced joints.

The powerhouse would be located on the left (south) side of the eastern branch of the Deserted River valley just upstream of Tsuahdi Creek. The valley is a steep-walled, flat-floored, glaciated hanging valley infilled to an unknown depth with glacial outwash. Much of the valley floor is swampy. An isolated bedrock knob is

located on the opposite side of the valley floor near the confluence of the north and east branches of the Deserted River.

Because of the steep bedrock slope and the unknown depth of glacial outwash, it has been assumed that a substantial platform would have to be excavated in the slope to found the powerhouse on competent diorite.

Approximately 500 m to the east of the powerhouse site is the trace of the Ashlu fault which forms the contact between batholiths of diorite and granodiorite. A south-westerly trending contact between the granodiorite and the argillites of the Gambier Group is located approximately 250 m west of the site.

The intake for the power tunnel would be located on the right bank of the Elaho River approximately 3 km upstream of the dam. For most of its length, the power tunnel would pass through hard, competent, plutonic rock (quartz diorite, diorite, and granodiorite). Quartz-rich granitic gneiss and migmatites might be encountered in limited zones.

It is not expected that metasedimentary Gambier Group rocks would be encountered. However, the tunnel would cross the Ashlu fault approximately 500 m east of the powerhouse. The fault is oriented almost orthogonally to the proposed alignment so it is anticipated that poor rock conditions would be encountered for only a short distance.

7.3 General Arrangement

The general arrangement of the dam and associated structures is shown on Fig. 7-3. The dam would be of the zoned-earthfill type with a vertical impervious core protected by an upstream transition and a downstream filter. The crest would be at El. 369, providing

9 m of freeboard above normal maximum reservoir level and 4.5 m of freeboard above the Probable Maximum Flood (PMF) level. The crest length would be 450 m and the maximum height would be approximately 145 m.

A gated chute spillway would be located on the left bank adjacent to the dam. With the spillway crest at El. 346, the spillway's two radial gates would be capable of releasing the design flood (PMF) peak outflow of 3,820 m^3/s with 4.5 m of surcharge (peak inflow is 5,200 m^3/s). The spillway would include a permanent fishwater release facility.

During construction of the dam, the Elaho River would be diverted by cofferdams through a shotcrete-lined tunnel located in the left abutment. The tunnel would be 10 m in diameter and approximately 700 m long and the diversion works would be capable of passing the 1-in-30-year design flood of 1,120 m^3/s. The diversion tunnel would subsequently be closed at the upstream portal by a steel bulkhead gate while a permanent concrete plug was constructed in the tunnel. After closure of the bulkhead gate and until the reservoir filled to the spillway approach channel, fishwater releases would be made through a temporary pipeline in the tunnel bypassing the bulkhead gate and passing through the plug. The pipeline would be sealed and grouted once the permanent release facility in the spillway became operable.

The general arrangement of the proposed power facilities is shown on Figs. 7-4 and 7-5.

The tunnel intake would be a reinforced concrete tower 60 m high housing a bulkhead gate and a fixed-wheel gate 6.9 m wide and 7.7 m high. A bridge would provide access to the tower from a road to be constructed on the right bank.

The 14.5-km power tunnel would be 'D' shaped with an arch diameter of 7.7 m and a height of 7.7 m. The invert would be concrete lined and it is estimated that 15 percent of the tunnel length would require a shotcrete lining. A concrete-lined rock trap would be provided just upstream of the surge shaft and lined tunnel section.

The concrete-lined surge shaft would be 22.5 m in diameter and approximately 100 m high. An air shaft would connect to the surface. Approximately 40 m beyond the surge shaft, the tunnel would transition into a 6.0-m diameter, concrete-lined, circular penstock and descend at an angle of 50° to the powerhouse level where it would resume a shallow gradient. The penstock would be steel lined in the upper bend and from the lower bend to the powerhouse. Just upstream of the powerhouse the steel lining would reduce to 4.0 m in diameter and then bifurcate into steel pipelines 2.65 m in diameter, each in its own short length of tunnel.

The surface powerhouse would consists of two unit bays, and an erection and service bay. Each unit bay would contain a Francis turbine, rated at 220,400 hp under a net head of 300 m, directly coupled to a synchronous generator capable of a maximum continuous output of 170 MW (190 MVA, 0.90 PF). Each unit would be equipped with a spherical inlet valve to permit independent shutdown and maintenance of the turbines. Although two units have been assumed for this study, any future studies would include a comparison of one and two-unit layouts.

The SF-6 gas-insulated switchgear would be located on the transformer deck on the downstream side of the powerhouse. One three-phase 13.8/230kV transformer would be provided for each generating unit.

7.4 Construction Considerations

Construction material sources were evaluated only on a reconnaissance basis, but adequate supplies of suitable materials appear to be present in the general project area. The floor of the upper Elaho valley is infilled with sands and gravels which should be suitable for the embankment dam shells and concrete aggregate. Another possible source of concrete aggregate is located on the right bank of the Elaho immediately upstream of its confluence with the Squamish River. For the purpose of cost estimates it was assumed that shell material would come from the upper Elaho valley with an average haul distance of 8 km. Concrete aggregates were assumed to come from the confluence source with an average haul distance of 6 km.

A large till deposit has been located on the left bank of the Squamish River, 3.5 km downstream of the mouth of the Elaho. While the suitability of the till has not been determined, it was assumed for the purpose of cost estimates that core material would come from this source, a haul distance of 11 km.

Concrete aggregates for the powerhouse were assumed to come from the Deserted River valley.

It has been assumed that the power tunnel would be driven by conventional drill-and-blast techniques from three main headings: the intake portal and two intermediate headings from an adit in the valley to the north-west of Ashlu Creek. The use of a tunnel boring machine should be studied if further project studies are authorized.

Materials from excavations in the Deserted River valley would be placed in an appropriately drained and landscaped spoil fill in an approved area in the valley. Soft material would be placed behind embankments of rock and granular material. Materials from exca-

vations in the Elaho valley would be used in the construction of permanent structures or placed in the reservoir area.

Heavy loads would be transported to the powerhouse area by barge.

The construction schedule is shown on Fig. 7-4. Both generating units would come into service 5 years after the award of the first contract.

7.5 Construction Cost Estimate

The estimated total construction cost of the proposed project at October 1982 prices is $661 million, exclusive of corporate overheads and interest during construction. A summary of itemized costs is shown in Table 7-1 and the estimated expenditure by fiscal years is shown in Table 7-2.

Contingencies have been applied at 30 percent to all direct costs. Costs of engineering, investigations and supervision have been included at 8.2 percent of the total direct construction cost plus contingencies. The costs of construction insurance and bonds have been included at 1.0 percent of the total direct construction cost plus contingencies.

Costs provided under the headings of Land and Rights, and Flowage provide for the direct or tangible costs of reservoir clearing, purchase or lease and reinstatement of land, Government royalties, and the realignment of roads subject to flooding by the reservoir. The sum for reservoir clearing assumes complete clearing up to the PMF flood level.

No provision has been made for transmission, environmental or socio-economic costs.

With an output of 224 average MW, the unit energy cost would be $2,951 per average kW.

SECTION 8.0 - ELAHO RIVER ALTERNATIVE

8.1 Project Description

The proposed project would consist of a dam and reservoir on the Elaho River and a power tunnel conveying water to a powerhouse situated on the right bank of the Elaho River approximately 2 km downstream of the dam (Fig. 7-1).

The damsite is accessible by logging road from Cheakamus powerhouse. Access to the powerhouse and other facilities on the right bank would be provided by new roads and a bridge across the Elaho River approximately 2 km downstream of the powerhouse.

The reservoir would be the same as for the Deserted Bay Alternative. However, with a tunnel capacity of 160 m^3/s (instead of 125 m^3/s) and no additional release to the Elaho River to preserve aquatic habitat, the 883 million m^3 of live storage would provide an average power flow of 89.8 m^3/s. This is 99 percent of the long-term average flow of the Elaho River, based on synthesized historic flows for the period October 1940 to September 1975.

With a tailwater level at El. 205, the project would develop a maximum gross head of 155 m and produce an annual average of 945 GW.h or 108 average MW. The firm energy would be 81 MW. With a generating capacity of 200 MW, the capacity factor would be 54 percent.

8.2 Site Geology

The damsite would be the same as for the Deserted Bay Alternative.

The powerhouse would be located on the right bank of the river 2 km downstream of the dam. The site is covered by talus at present and the underlying bedrock could not be examined. It is, however, believed to be competent quartz diorite.

The intake for the power tunnel would be located on the right bank of the river, 400 m upstream of the dam. The intake would be in sound quartz diorite and would be avalanche free. For most of its length, the power tunnel would pass through the same quartz diorite; minor zones of gneissic rock might also be encountered. The quartz diorite contains a few hard, dark grey, mafic-rich xenoliths and is cross cut by andesite dykes 0.15 m to 0.5 m thick. Towards the damsite, the dykes appear to trend 160° to 170° and account for some linear features exposed on the bedrock slope.

Jointing in the quartz diorite is generally tight and widely spaced. Foliation is poorly developed and is generally near vertical and trends 130°. The tunnel alignment would be generally parallel to the foliation. The abrupt changes in the river channel 100 m and 1.9 km downstream of the proposed dam axis could indicate zones of weak rock such as a dyke (or dykes) and accompanying closely-spaced joints. These zones would probably be encountered in the tunnel.

8.3 General Arrangement

The general arrangement of the dam and associated structures would be essentially the same as that for the Deserted Bay Alternative shown on Fig. 7-3, except that provision for post-construction fishwater releases would be unnecessary.

The general arrangement of the proposed power facilities is shown on Fig. 8-1.

The power intake would be a reinforced concrete tower 60 m high, housing a bulkhead gate and a fixed-wheel gate 7.45 m wide and 8.25 m high. A bridge would provide access to the tower from a road to be constructed on the right bank.

The power tunnel would be 'D' shaped with a diameter of 8.25 m. The invert would be concrete lined and it is estimated that 15 percent of the tunnel's 2.6-km length would require a shotcrete lining. A concrete-lined rock trap would be provided just upstream of the surge shaft.

The concrete-lined surge shaft would be 13.0 m in diameter and approximately 100 m high. The shaft would extend to the surface. Approximately 40 m beyond the surge shaft, the tunnel would transition into a 6.0-m diameter, concrete-lined, circular penstock and descend at an angle of 50° to the powerhouse level where it would resume a shallow gradient. The transition and upper bend would be steel lined, as would the section from the lower bend to the powerhouse. Just upstream of the powerhouse, the steel lining would bifurcate into steel pipelines 3.15 m in diameter, each in its own short length of tunnel.

The surface powerhouse would consist of two unit bays, and an erection and service bay. Each unit bay would contain a Francis turbine, rated at 119,800 hp under a net head of 132 m, directly coupled to a synchronous generator capable of a maximum continuous output of 100 MW (110 MVA, 0.90 PF). Each penstock would be equipped with a spherical inlet valve to permit independent shutdown and maintenance of the turbines. Although two units have been assumed for this study, any future studies would include a comparison of one and two-unit layouts.

The SF-6 gas-insulated switchgear would be located on the transformer deck on the downstream side of the powerhouse. One three-

phase 13.8/230 kV transformer would be provided for each generating unit.

8.4 Construction Considerations

The sources of construction materials and construction methods would be generally the same as the Deserted Bay Alternative except that all heavy loads could be transported by road. It was assumed that the power tunnel would be driven from the intake portal.

The proposed construction schedule is shown on Fig. 8-1. Both generating units would come into service 4 years and 4 months after the award of the first contract.

8.5 Construction Cost Estimate

The estimated total construction cost of the proposed project at October 1982 prices is $468 million, exclusive of corporate overheads and interest during construction. A summary of itemized costs is shown in Table 8-1 and estimated expenditure by fiscal years is shown in Table 8-2. The estimate is based on the same criteria and assumptions as the Deserted Bay Alternative.

With an output of 108 average MW, the unit energy cost would be $4,333 per average kW.

SECTION 9.0 - CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

1. The Deserted Bay Alternative would produce energy at a unit cost comparable to projects currently being considered for future additions. Capacity, energy and cost data are:

Generating Capacity	-	340 MW
Firm Energy	-	172 Av. MW
Average Energy	-	224 Av. MW
Construction Cost	-	$661 million
Unit Energy Cost	-	$2,951/Av. kW

In addition to its prime function to generate electric power, the project would reduce Elaho floods and could provide significant flood control benefits to the Squamish valley.

The project would encroach on Indian Reserve I.R. 15 at Deserted Bay. I.R. 15 could be avoided by routing the power tunnel to the north of the Deserted River valley and locating the powerhouse on the shore of Jervis Inlet in the vicinity of Lot 894 to the northwest of Deserted Bay. Such a layout would require a tunnel 4.5 km longer and, although no detailed studies have been performed, it is estimated that the construction cost would increase by 5-10 percent.

2. The Elaho River Alternative would produce energy at a cost almost 50 percent higher than the Deserted Bay Alternative. Capacity, energy and cost data are:

Generating Capacity	-	200 MW
Firm Energy	-	81 Av. MW

Average Energy	-	108 Av. MW
Construction Cost	-	$468 million
Unit Energy Cost	-	$4,333/Av. kW

The project could provide somewhat smaller flood control benefits than the Deserted Bay Alternative. The Elaho River dam is a significantly greater proportion of the total cost of the Elaho River Alternative than of the Deserted Bay Alternative. The conservative choice of an earthfill dam at site 7 may prove unwarranted with further study of the sites and type of dam. Since this further study would be required for the Deserted Bay Alternative, the Elaho River Alternative could be reviewed in the future at little extra cost.

9.2 Recommendations

1. It is recommended that consideration be given to proceeding with feasibility studies for the Deserted Bay Alternative and for an alternative diversion scheme avoiding I.R. 15 using a tunnel to the north of the Deserted River valley. Two years of study are envisaged. First-year investigations would concentrate on identifying the most suitable site and type of dam. Tunnels and powerhouse sites would be investigated in the second year.

2. It is recommended that feasibility studies for the Elaho River Alternative be considered only if both tidewater diversion alternatives are found to be unacceptable or infeasible.

3. It is recommended that feasibility studies for the Deserted Bay Alternative include:

a) Topographic mapping at suitable metric scales and contour intervals, both for the general project area and for the sites of specific project structures.

b) Hydrologic studies to firm up power flows, and the spillway and construction-diversion design floods. (Existing meteorological and hydrometric stations should be maintained and additional stations installed to enable definition of areal variations in precipitation and runoff within the basin. The effect of glacier runoff on long-term average streamflow merits particular attention).

c) Installation of at least one suspended sediment station on the Elaho River. (The objective of the sediment measuring program would be to provide reliable estimates of reservoir sedimentation rates and degradation and aggradation of river channels downstream of the proposed damsite).

d) A river regime and morphology study of the entire reach of the Elaho River from damsite 6 to the Squamish estuary to establish baseline information and assess the impacts of the proposed reservoir.

e) Subsurface investigations, including geophysical surveys and drilling in the buried channel area at damsite 6, and angled diamond drill holes beneath the Elaho River at both damsite 6 and 7.

f) Geologic mapping of the dam and powerhouse sites at a scale of 1:2500, and a 1:10000 scale regional geological mapping program emphasizing lithology and structures in the area between the Elaho River and Jervis Inlet.

g) An economic study of the flood control benefits resulting from regulation of the Elaho River.

h) An ice observation program for the Elaho River, with the objective of identifying patterns of freeze-up and break-up and of recording relevant temperature and ice thickness data.

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TABLE 5-1

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

ECONOMIC CRITERIA

Discount Rate[1]	4%
Value of Firm Energy	19.9 mills/kW.h
Value of Secondary Energy	10.0 mills/kW.h
Annual Cost Factor[2]	5.8%

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[1] Net of inflation

[2] Net of inflation and without grants and taxes

TABLE 5-2

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

MONTHLY ENERGY VALUE
WEIGHTING FACTORS

October	1.2	April	0.9
November	1.2	May	0.9
December	1.1	June	0.8
January	1.1	July	0.8
February	0.9	August	1.0
March	0.9	September	1.2

TABLE 6-1

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

FLOOD CONTROL EFFECT OF
LIVE STORAGE PROVIDED
FOR POWER GENERATION

Month	Monthly[1] Medial Reservoir Target Level (m)	Storage[2] Volume Available (million m^3)	Storm[3] Return Period (Years)
Oct.	357.6	80	Less than average flood
Nov.	352.8	240	75
Dec.	348.1	380	>500
Jan.	343.0	540	>500
Feb.	338.9	650	>500
Mar.	335.6	750	>500
Apr.	333.4	790	>500
May	334.8	760	>500
Jun.	341.3	610	>500
Jul.	350.9	300	400
Aug.	358.0	70	Less than average flood
Sep.	360.0	Nil	-

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1 Mean of the target levels for the beginning and end of the month.

2 Storage available up to normal maximum reservoir level, El. 360.

3 Return period of storm which has 3-day runoff volume equal to available storage.

TABLE 6-2

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

EFFECT OF PROVIDING
SURCHARGE STORAGE
FOR FLOOD CONTROL

Reservoir Inflow[1]		2 m Surcharge Storage			4.5 m Surcharge Storage		
Flood Return Period (Years)	3-day Volume ($x10^6 m^3$)	Constant[2] Reservoir Outflow (m^3/s)	Return[3] Period (Years)	Return[4] Period of Reduced Flow at Squamish (Years)	Constant[2] Reservoir Outflow (m^3/s)	Return[3] Period (Years)	Return[4] Period of Reduced Flow at Squamish (Years)
10	160	347	1.2	4	39	-	1.5
20	185	444	1.3	8	135	-	3
50	220	579	2.0	20	270	-	7
100	255	714	3.0	50	405	1.25	17

1 Dam at site 7.

2 Constant outflow required to maintain reservoir level within the specified surcharge.

3 Return period of outflow if released into the Elaho River. For the Deserted Bay Alternative the release to the Elaho River would be reduced by an amount up to 125 m^3/s released through the powerhouse at Deserted River.

4 Assuming uniform precipitation throughout the area of contributary flows.

TABLE 7-1

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY
DESERTED BAY ALTERNATIVE
2 UNITS - CAPACITY 340 MW

ESTIMATE OF CONSTRUCTION COSTS
($ Millions)

1.	Land and Rights		7.15
2.	Flowage		16.14
3.	Area access		7.44
4.	Site access		9.00
5.	Site clearing		0.10
6.	Diversion tunnels and coffer dams		26.50
7.	Embankment dam		78.04
8.	Spillway		41.31
9.	Power intake		7.81
10.	Power tunnel		130.96
11.	Surge shaft		18.69
12.	Penstocks		23.17
13.	Powerhouse and switchyard		
	Civil		20.89
	Mechanical		13.27
	Electrical		34.00
14.	Tailrace channel improvements		5.05
15.	Construction Services		26.37
	TOTAL DIRECT CONSTRUCTION COST		465.89
	Contingencies	139.74	
	Engineering, Investigations, Supervision	49.65	
	Construction Insurance and Bonds	6.06	
	TOTAL INDIRECT CONSTRUCTION COST	195.45	195.45
	TOTAL CONSTRUCTION COST		661.34

Note: Costs are based on October 1982 prices. Transmission, environmental or social costs associated with the project are not included. Interest during construction and corporate overhead costs are also not included.

TABLE 7-2

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY
DESERTED BAY ALTERNATIVE

ESTIMATE OF CONSTRUCTION EXPENDITURES BY FISCAL YEARS
($ Millions)

Fiscal Year[1]	Annual Capital Expenditures[2]
1	141.13
2	204.29
3	185.60
4	77.04
5	53.28
Total	661.34

1 Fiscal year is 1 April to 31 March.

2 All costs are based on October 1982 price levels.
For other footnotes see Table 7-1.

TABLE 8-1

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY
ELAHO RIVER ALTERNATIVE
2 UNITS - CAPACITY 200 MW

ESTIMATE OF CONSTRUCTION COSTS
($ Millions)

1.	Land and Rights		5.98
2.	Flowage		16.10
3.	Area access		5.27
4.	Site access		5.50
5.	Site clearing		0.10
6.	Diversion tunnels and cofferdams		26.48
7.	Embankment dam		78.04
8.	Spillway		41.31
9.	Power intake		8.21
10.	Power tunnel		28.88
11.	Surge shaft		13.79
12.	Penstocks		10.87
13.	Powerhouse and switchyard		
	Civil		21.77
	Mechanical		14.99
	Electrical		32.50
14.	Tailrace channel improvements		1.13
15.	Construction Services		18.65
	TOTAL DIRECT CONSTRUCTION COST		329.57
	Contingencies	98.84	
	Engineering, Investigations, Supervision	35.12	
	Construction Insurance and Bonds	4.28	
	TOTAL INDIRECT CONSTRUCTION COST	138.24	138.24
	TOTAL CONSTRUCTION COST		467.81

Note: Costs are based on October 1982 prices. Transmission, environmental or social costs associated with the project are not included. Interest during construction and corporate overhead costs are also not included.

TABLE 8-2

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY
ELAHO RIVER ALTERNATIVE

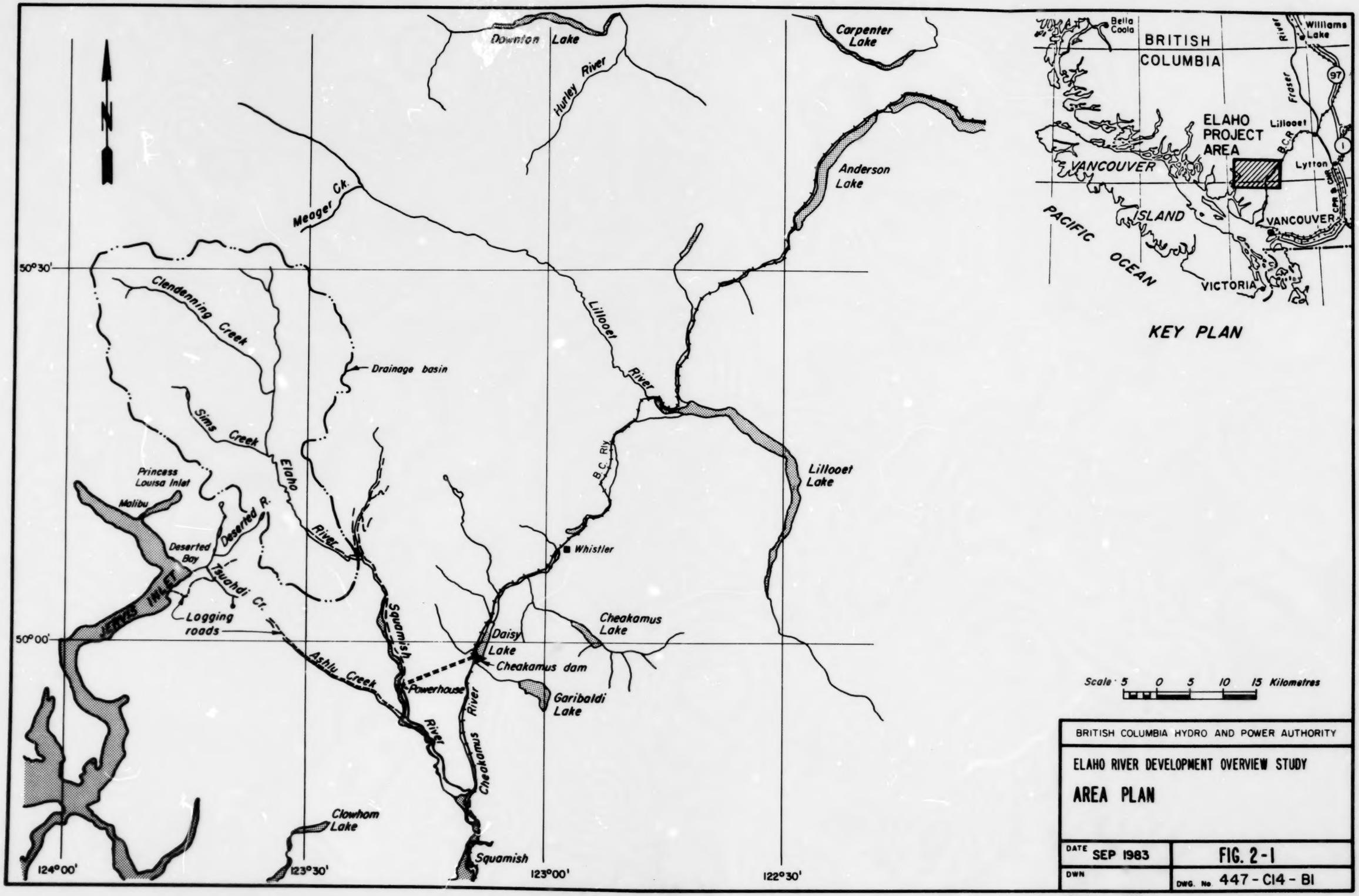
ESTIMATE OF CONSTRUCTION EXPENDITURES BY FISCAL YEARS
($ Millions)

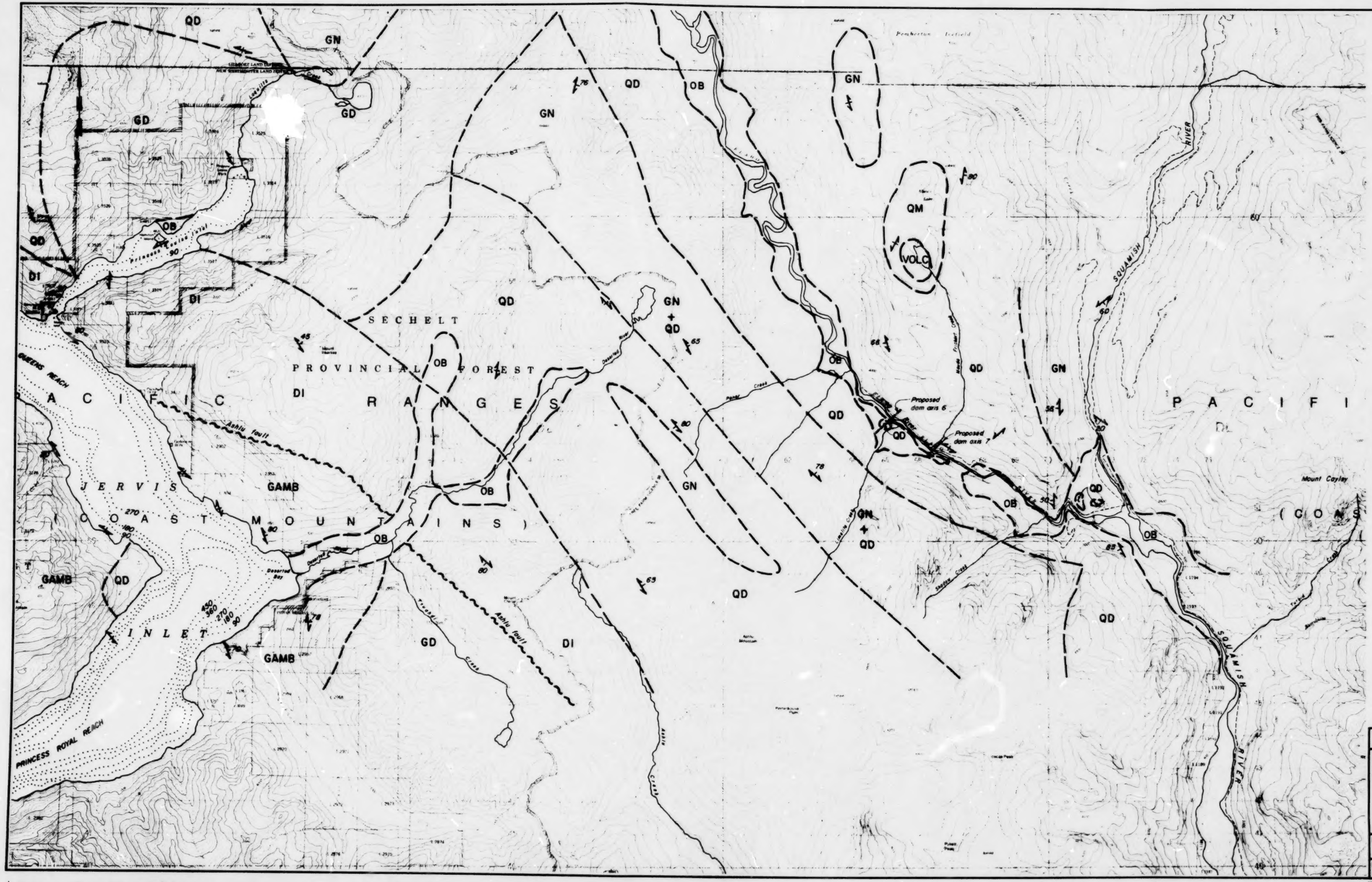
Fiscal Year[1]	Annual Capital Expenditures[2]
1	131.33
2	127.00
3	96.72
4	112.76
Total	467.81

[1] Fiscal year is 1 April to 31 March.

[2] All costs are based on October 1982 price levels.
For other footnotes see Table 8-1.

FIGURES


N
Downton Lake
Hurley River
Carpenter Lake
Anderson Lake
Meager Ck.
50°30'
Clendenning Creek
Drainage basin
Sims Creek
Elaho River
Lillooet River
B.C. Rly
Lillooet Lake
Princess Louisa Inlet
Malibu
Deserted R.
Deserted Bay
Tsuohdi Ck.
Logging roads
Whistler
Squamish River
Cheakamus Lake
Daisy Lake
Cheakamus dam
50°00'
Ashlu Creek
Powerhouse
Garibaldi Lake
Cheakamus River
Clowhom Lake
Squamish
124°00'
123°30'
123°00'
122°30'
Bella Coola
BRITISH COLUMBIA
Williams Lake
Fraser River
97
ELAHO PROJECT AREA
Lillooet
B.C.R.
Lytton
VANCOUVER
CPR & CNR
PACIFIC OCEAN
ISLAND
VANCOUVER
VICTORIA
KEY PLAN
Scale 5 0 5 10 15 Kilometres
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
ELAHO RIVER DEVELOPMENT OVERVIEW STUDY
AREA PLAN
DATE SEP 1983
FIG. 2-1
DWN
DWG. No. 447 - C14 - B1
REPORT No. H1895


QD
GN
GD
OB
DI
QM
VOLC
GAMB
SECHELT
PROVINCIAL FOREST
RANGES
COAST MOUNTAINS
INLET
Ashlu fault
Proposed dam axis 6
Proposed dam axis 7
Mount Cayley
SQUAMISH RIVER
QUEENS REACH
PRINCESS ROYAL REACH
Pemberton Icefield
NOTES:
1. REGIONAL GEOLOGY
OPEN FILE 482.
(1970, 1974) W.W
GSC REPORTS.
2. BATHYMETRIC CONT
HYDROGRAPHIC CHA
LEGEND:
OB UNCONSOLID
DEPOSITS
VOLC BASALT FLO
GAMB (GAMBIER G
CONGLOMERA
GN GRANITIC G
DIORITE (P
GD GRANODIORI
QD QUARTZ DIO
DI DIORITE
QM QUARTZ MON
MAP SYMBOL
ASSUMED CO
REGIONAL F
(INCLINED,
ASSUMED FA
BATHYMETRI
CONTOUR INTERVAL = 100
Scale: 0 1000
BRITISH COLUMB
ELAHO RIVER DEVELO
REGIONAL GEOL
DATE SEP 1983
DWN
REPORT No. H1985

NOTES:

1. REGIONAL GEOLOGY ADAPTED FROM GEOLOGICAL SURVEY OF CANADA OPEN FILE 482. GEOLOGY BY J.A. RODDICK AND G.W. WOODSWORTH (1970, 1974) W.W. HUTCHINSON (1970) AND FROM EARLIER GSC REPORTS.
2. BATHYMETRIC CONTOURS (90 m INTERVAL) TAKEN FROM 1981 HYDROGRAPHIC CHART #3589 JERVIS INLET AND APPROACHES.

LEGEND:

OB	UNCONSOLIDATED ALLUVIAL, FLUVIAL, AND GLACIAL DEPOSITS	
VOLC	BASALT FLOWS (PLEISTOCENE)	
GAMB	(GAMBIER GROUP) - TUFFS, BRECCIAS, ARGILLITE, CONGLOMERATE AND PHYLLITE (LOWER CRETACEOUS)	
GN	GRANITIC GNEISS, MIGMATITE, SCHIST, QUARTZ DIORITE (PALEOZOIC)	
GD	GRANODIORITE	UNKNOWN AGE
QD	QUARTZ DIORITE	
DI	DIORITE	
QM	QUARTZ MONZONITE	

MAP SYMBOLS

- ASSUMED CONTACTS
- 50 REGIONAL FOLIATION, SCHISTOSITY (INCLINED, VERTICAL, DIP UNKNOWN)
- ASSUMED FAULT
- BATHYMETRIC CONTOUR (APPROXIMATE) INTERVAL = 90 m

CONTOUR INTERVAL = 100 ft.

Scale: 0 1000 2000 3000 4000 5000 Metres

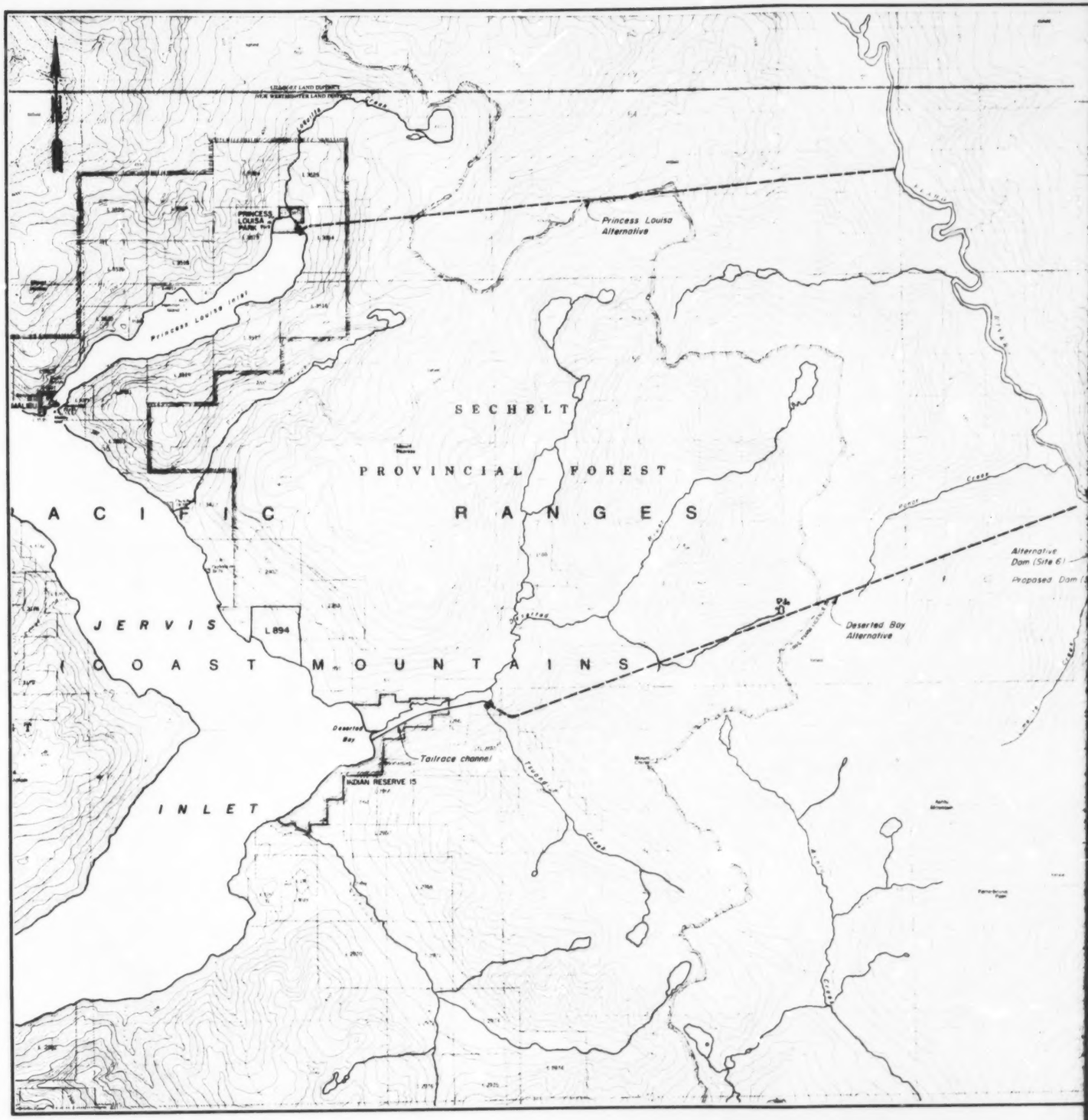
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

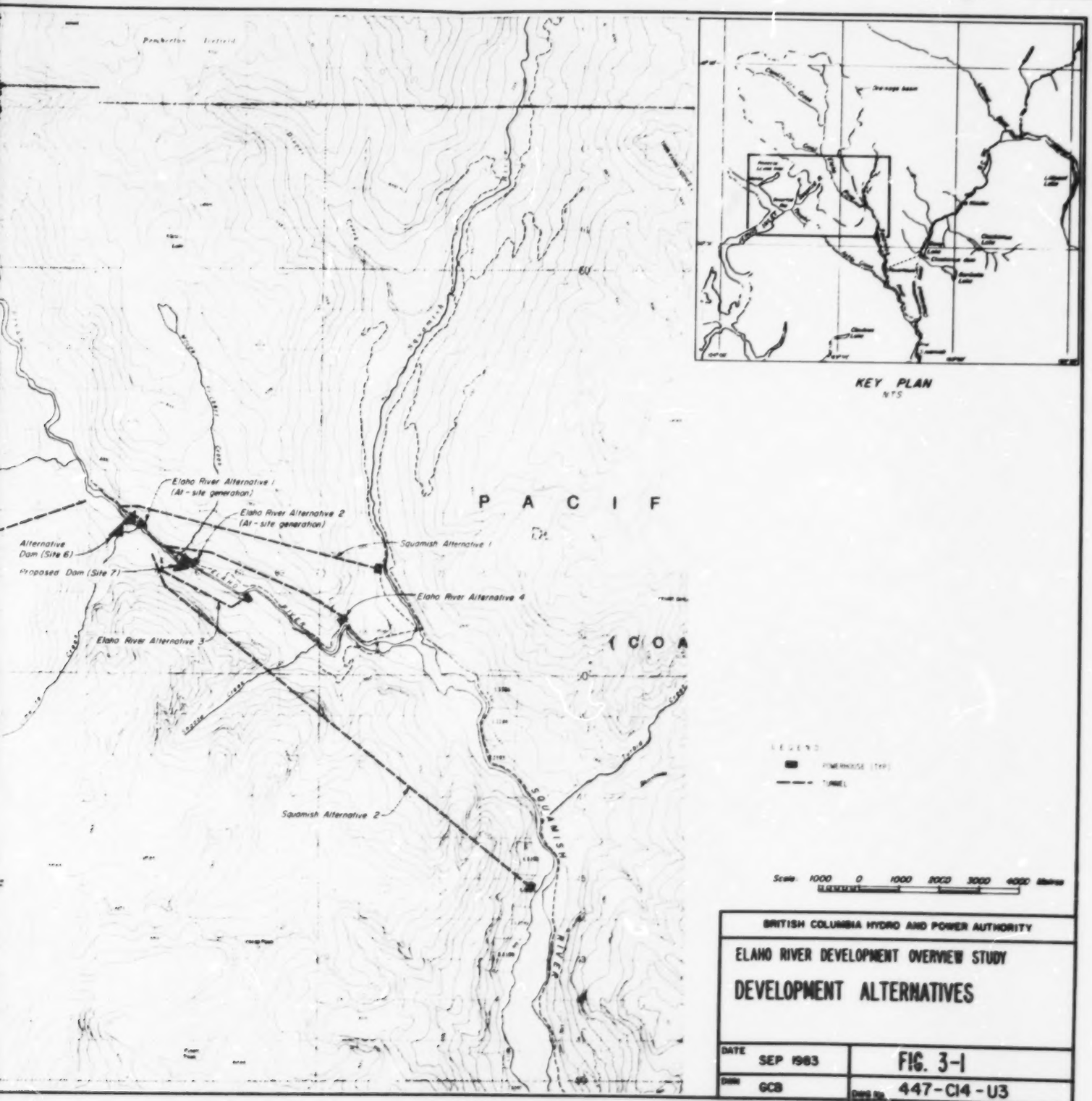
ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

REGIONAL GEOLOGY

DATE SEP 1983	FIG. 2-2
DWN	DWG No. 447-C14-U4

REPORT No H1895





KEY PLAN
N.T.S.

LEGEND

Scale 1000 0 1000 2000 3000 4000 Metres

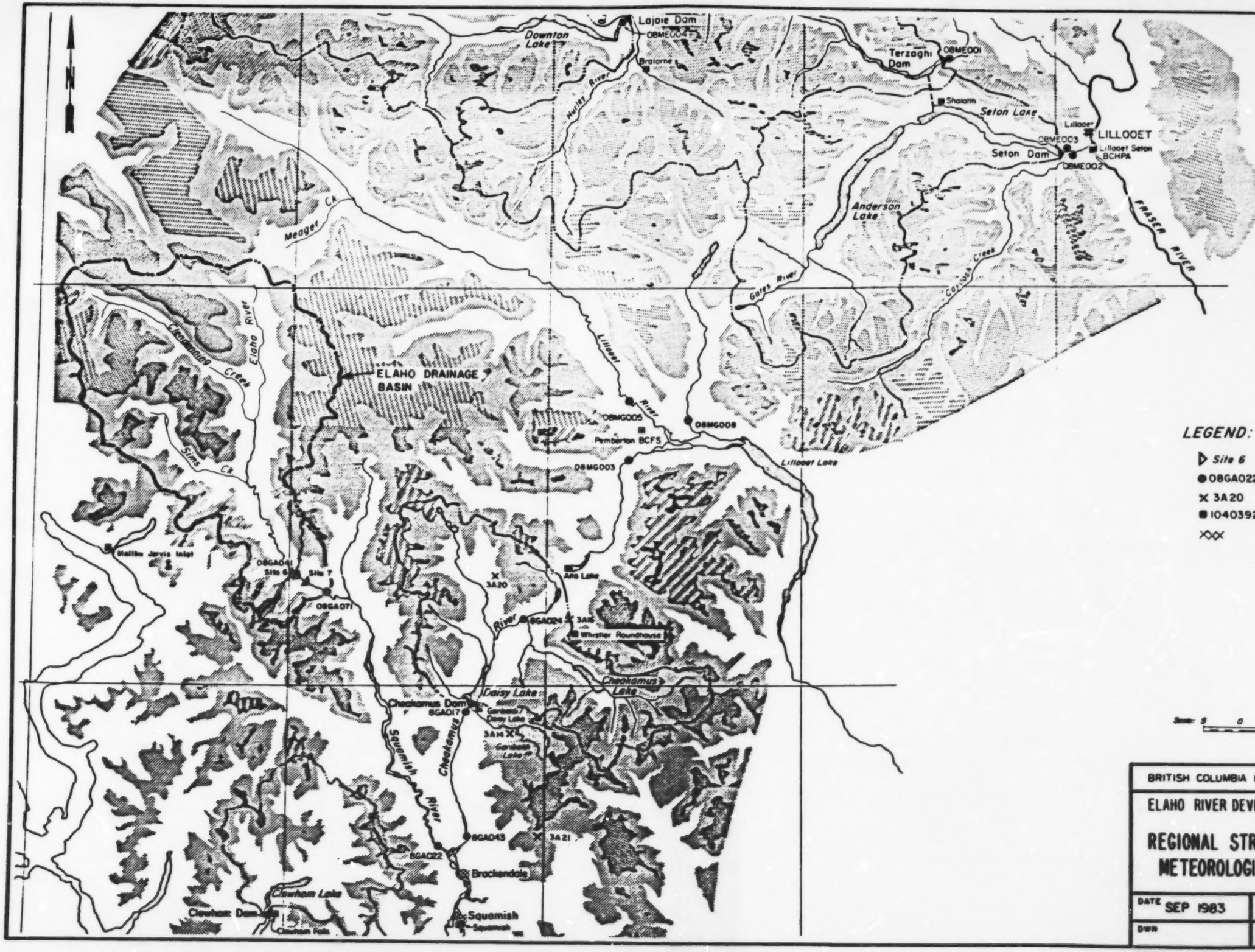
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

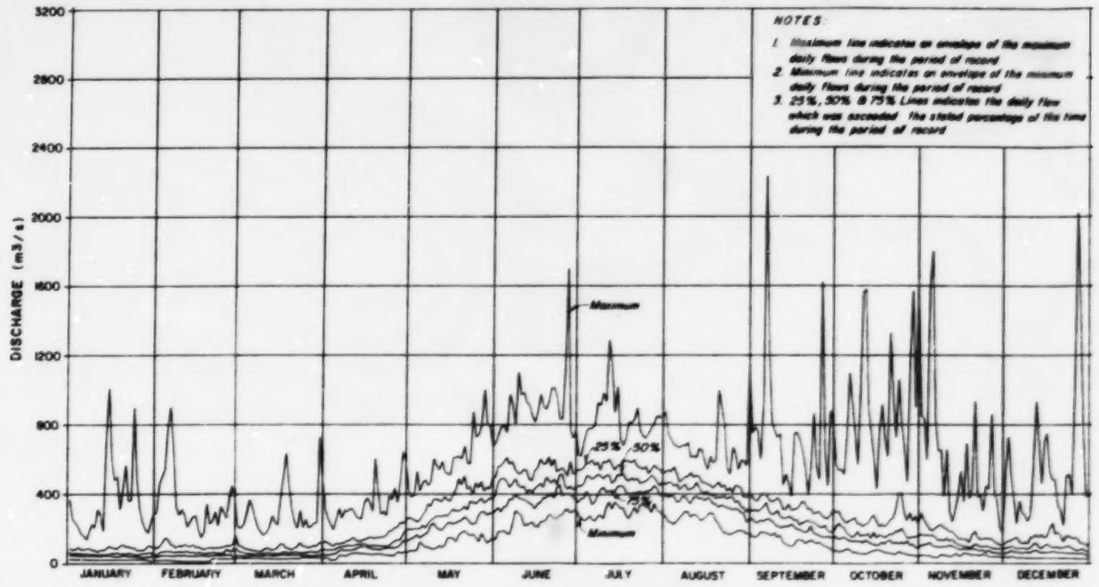
ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

DEVELOPMENT ALTERNATIVES

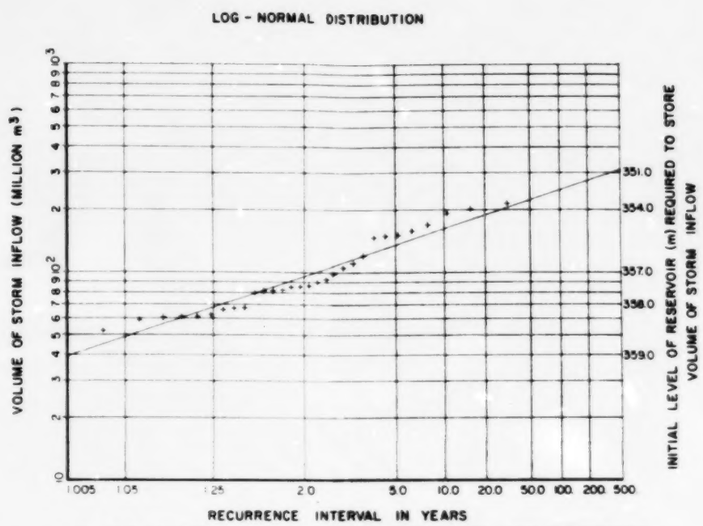
DATE SEP 1983	FIG. 3-1
DWN GCB	DWG No. 447-C14-U3

REPORT No H1565

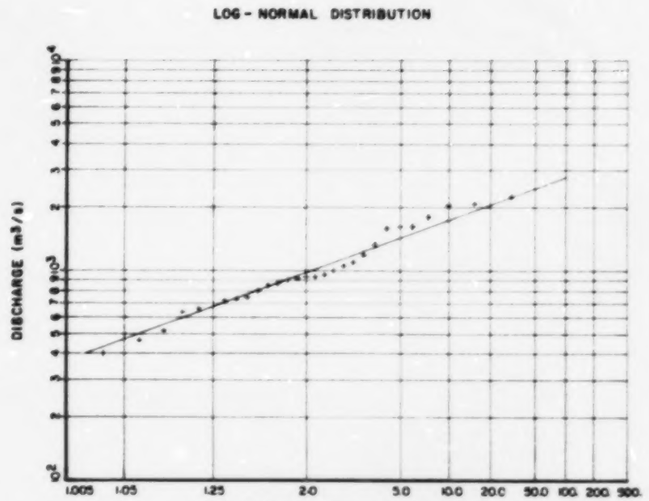

N
Lajoie Dam
08ME004
Downton Lake
Hurley River
Bralorne
Terzaghi Dam
08ME001
Shalalth
Seton Lake
Lillooet
LILLOOET
08ME003
Lillooet Seton BCHPA
Seton Dam
08ME002
FRASER RIVER
Anderson Lake
Meager Ck
Gates River
Cayoosh Creek
Lillooet River
Elaho River
Tenquille Creek
Sims Ck
ELAHO DRAINAGE BASIN
08MG005
Pemberton BCFS
08MG008
08MG003
Lillooet Lake
Malibu Jervis Inlet
08GA041
Site 6
Site 7
08GA071
3A20
Alta Lake
08GA024
3A15
Whistler Roundhouse
Daisy Lake
Cheakamus Lake
Cheakamus Dam
08GA017
Garibaldi
Daisy Lake
3A14
Garibaldi Lake
Squamish River
Cheakamus
08GA043
3A21
08GA022
Brackendale
Squamish
Cheekye
Cheekye Fan
Cheekye River
Cheekye Ridge
Cheekye Fan
Cheekye River
Cheekye Ridge
Cheekye Fan
Cheekye River
Cheekye Ridge



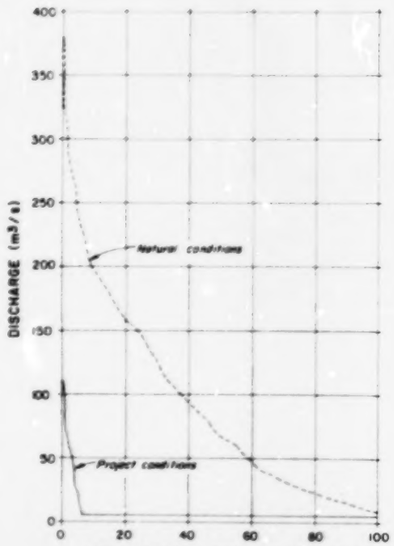
FLOW PROBABILITY CURVE SQUAMISH RIVER AT BRACKENDALE
WSC GAUGING STATION 08GA022
1922 - 1980



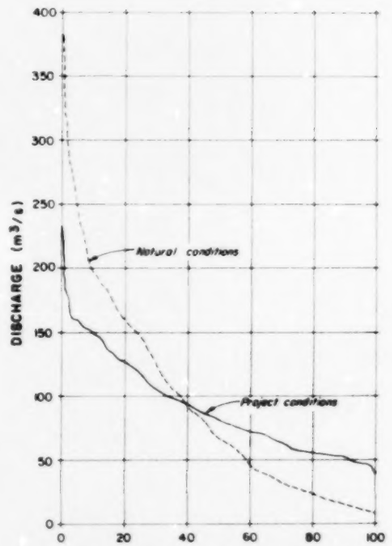
3 - DAY FLOOD VOLUME FREQUENCY PLOT AND RESERVOIR DRAWDOWN REQUIRED TO STORE STORM INFLOW AT DAMSITE 7



ANNUAL FLOOD FREQUENCY PLOT SQUAMISH RIVER AT BRACKENDALE
WSC GAUGING STATION 08GA022


DISCHARGE (m3/s)
Natural conditions
Project conditions
PERCENTAGE OF TIME THAT DISCHARGE WOULD HAVE BEEN EQUALLED OR EXCEEDED DURING THE PERIOD 1941-1975

DESERTED BAY ALTERNATIVE


DISCHARGE (m3/s)
Natural conditions
Project conditions
PERCENTAGE OF TIME THAT DISCHARGE WOULD HAVE BEEN EQUALLED OR EXCEEDED DURING THE PERIOD 1941-1975

ELAHO RIVER ALTERNATIVE

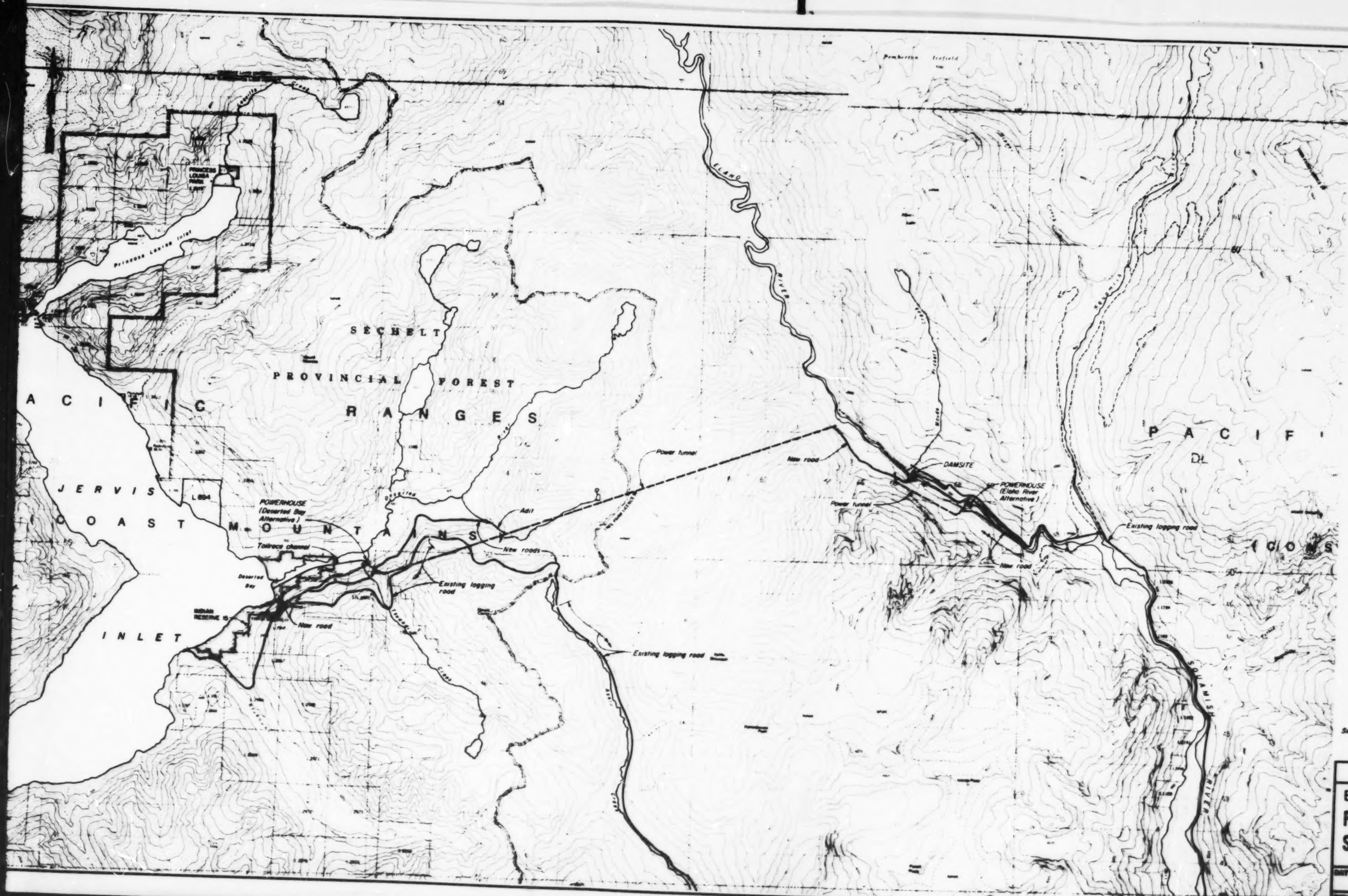
EFFECT OF PROJECT OPERATION ON MEAN MONTHLY DISCHARGES OF THE ELAHO RIVER AT DAMSITE 7

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

TYPICAL HYDROGRAPH, FLOOD FREQUENCY PLOTS AND EFFECT OF PROJECT OPERATION

DATE	FIG. 4-2
SEP 1983	
DWN	DWG No. 447-C14-D10

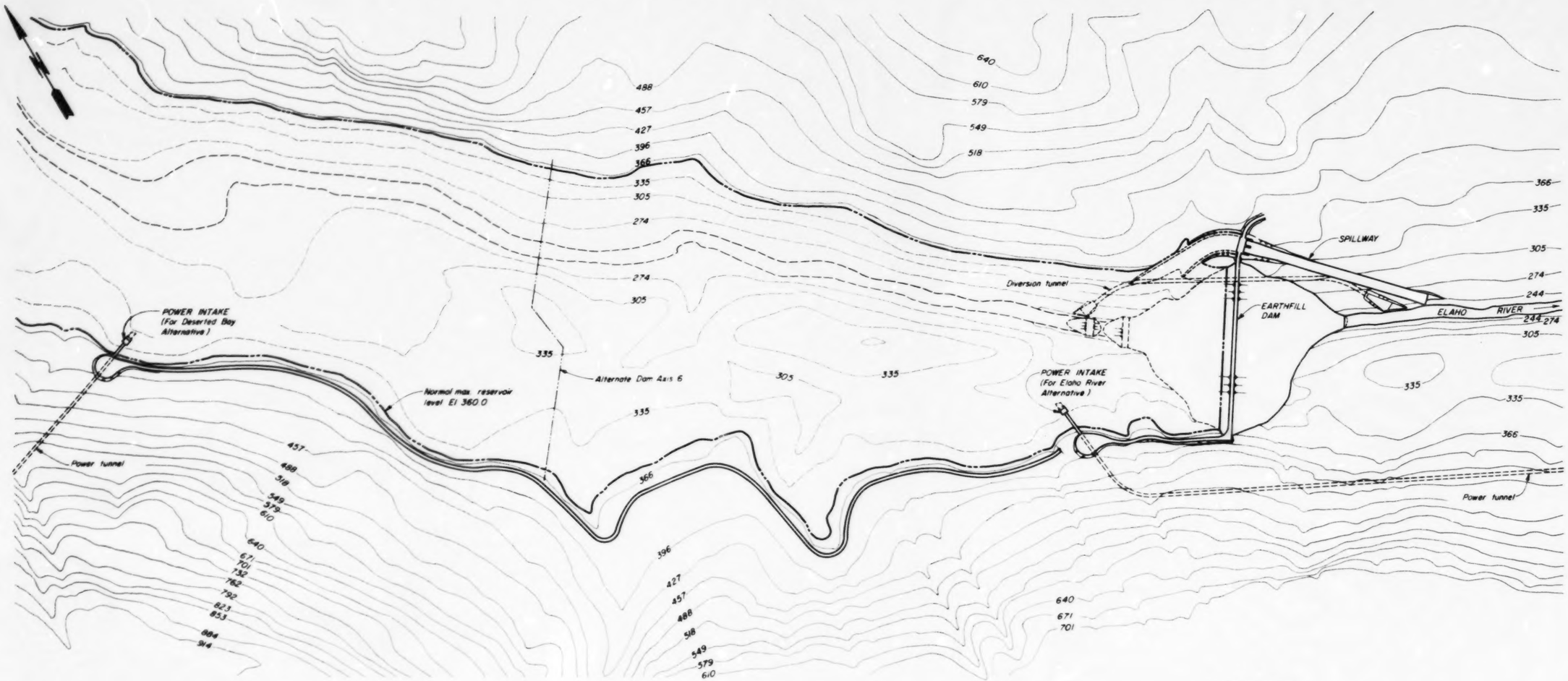


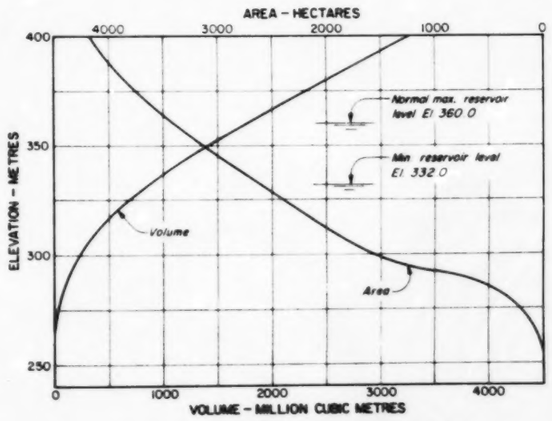
BRITISH COLUMBIA HYDRO AND POWER

ELAHO RIVER DEVELOPMENT OVERVIEW S

PROJECT ALTERNATIVES
SCHEMATIC LAYOUT AND ACC

DATE SEP 1983	FIG. 7-1
DWG GC / 6C3	447-C14





RESERVOIR AREA & VOLUME CURVES

Scale 100 0 100 200 300 400 Metres

All dimensions are in metres, unless otherwise shown

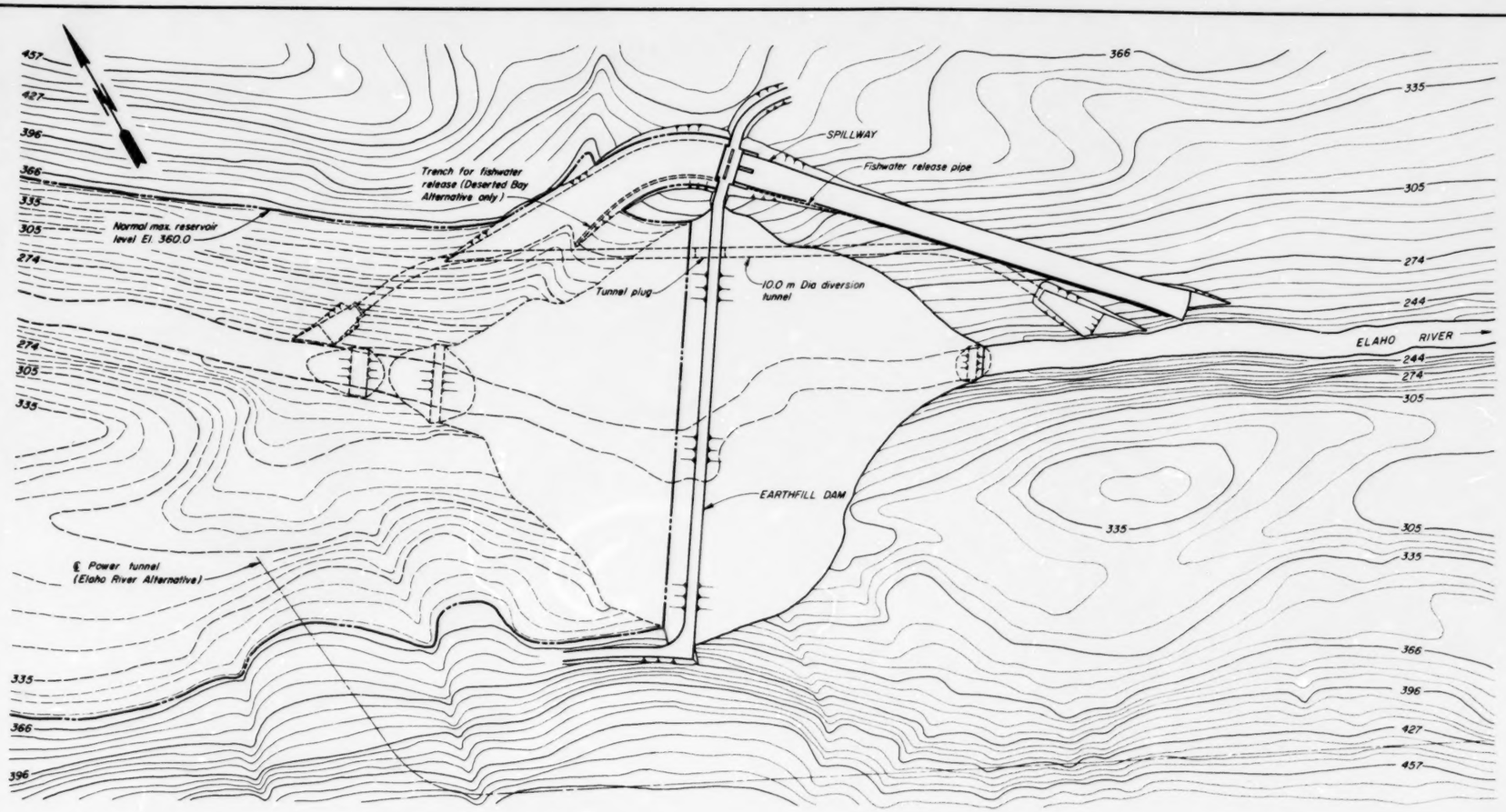
BRITISH COLUMBIA HYDRO AND POWER AUTHO

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

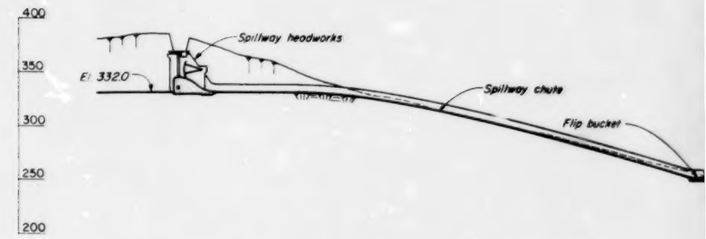
DAM AND INTAKES
SITE PLAN (SITE 7)
RESERVOIR AREA AND VOLUME CUR

DATE SEP 1983	FIG. 7-2
DWN GCB	DWG No 447-C14-U5

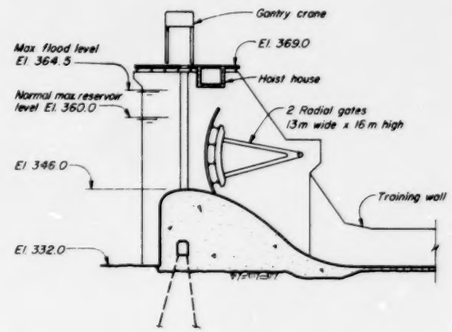
REPORT No. H1595



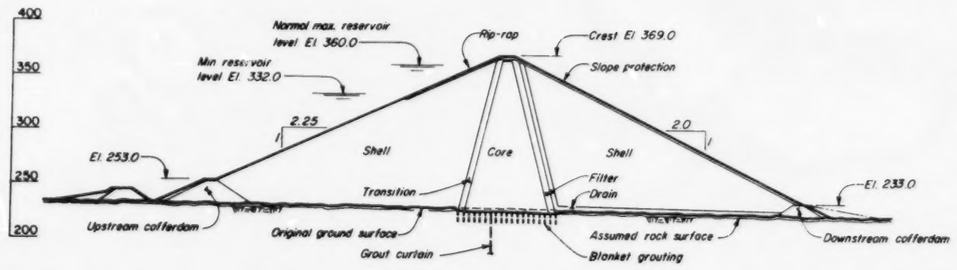
PLAN
Scale A



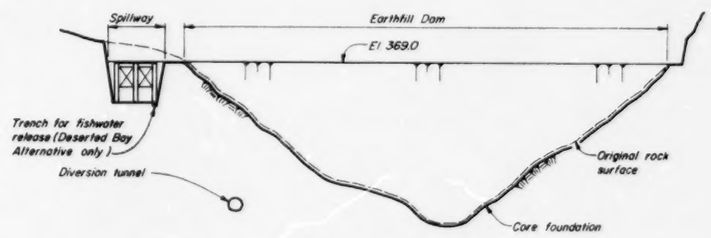
SECTION THROUGH SPILLWAY
Scale A



SECTION THROUGH SPILLWAY HEADWORKS
Scale B



SECTION THROUGH EARTHFILL DAM
Scale A



DEVELOPED UPSTREAM ELEVATION
Scale A

Scale: B 10 0 10 20

Scale: A 50 0 50 100

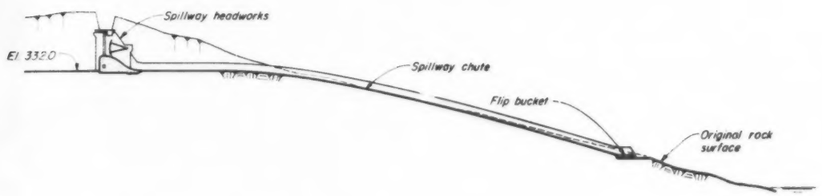
All dimensions are in metres, unless otherw

BRITISH COLUMBIA HYDRO

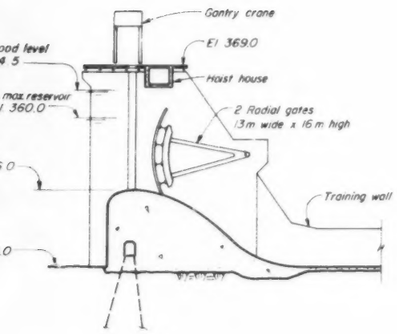
ELAHO RIVER DEVELOPMENT O
DAM (SITE 7)
PLAN AND SECTIONS
GENERAL ARRANGEMEN

DATE SEP 1983	F
DWN GCB	DWG No. 4

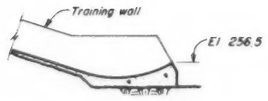
REPORT No. H1595



SECTION THROUGH SPILLWAY
Scale A



SECTION THROUGH SPILLWAY HEADWORKS
Scale B



SECTION THROUGH FLIP BUCKET
Scale B

Scale: B 10 0 10 20 30 40 Metres

Scale: A 50 0 50 100 150 200 Metres

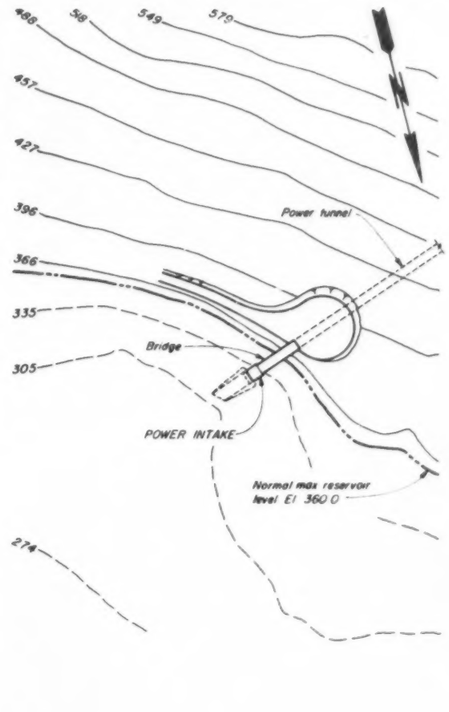
All dimensions are in metres, unless otherwise shown

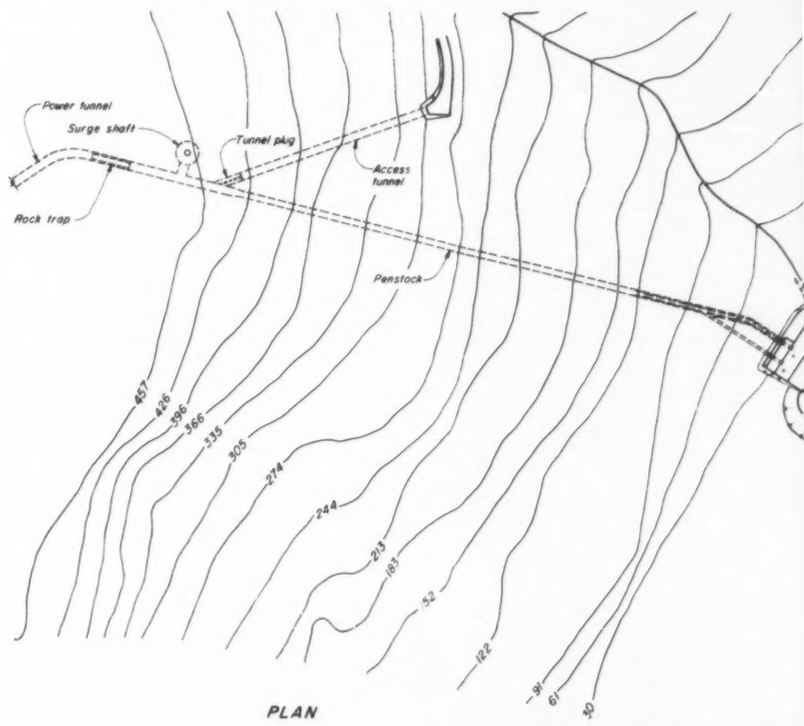
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

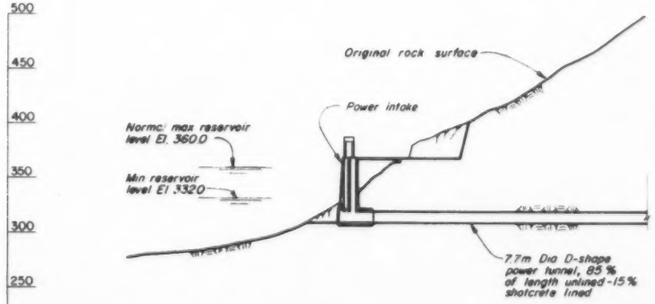
DAM (SITE 7)
PLAN AND SECTIONS
GENERAL ARRANGEMENT

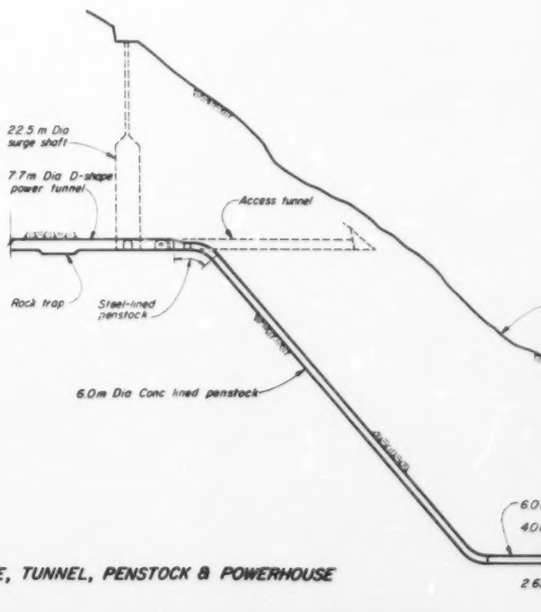
DATE SEP 1983	FIG. 7-3
DWN GCB	DWG No 447-C14-U6



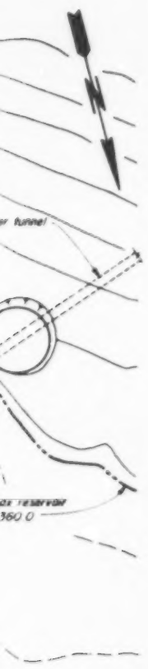


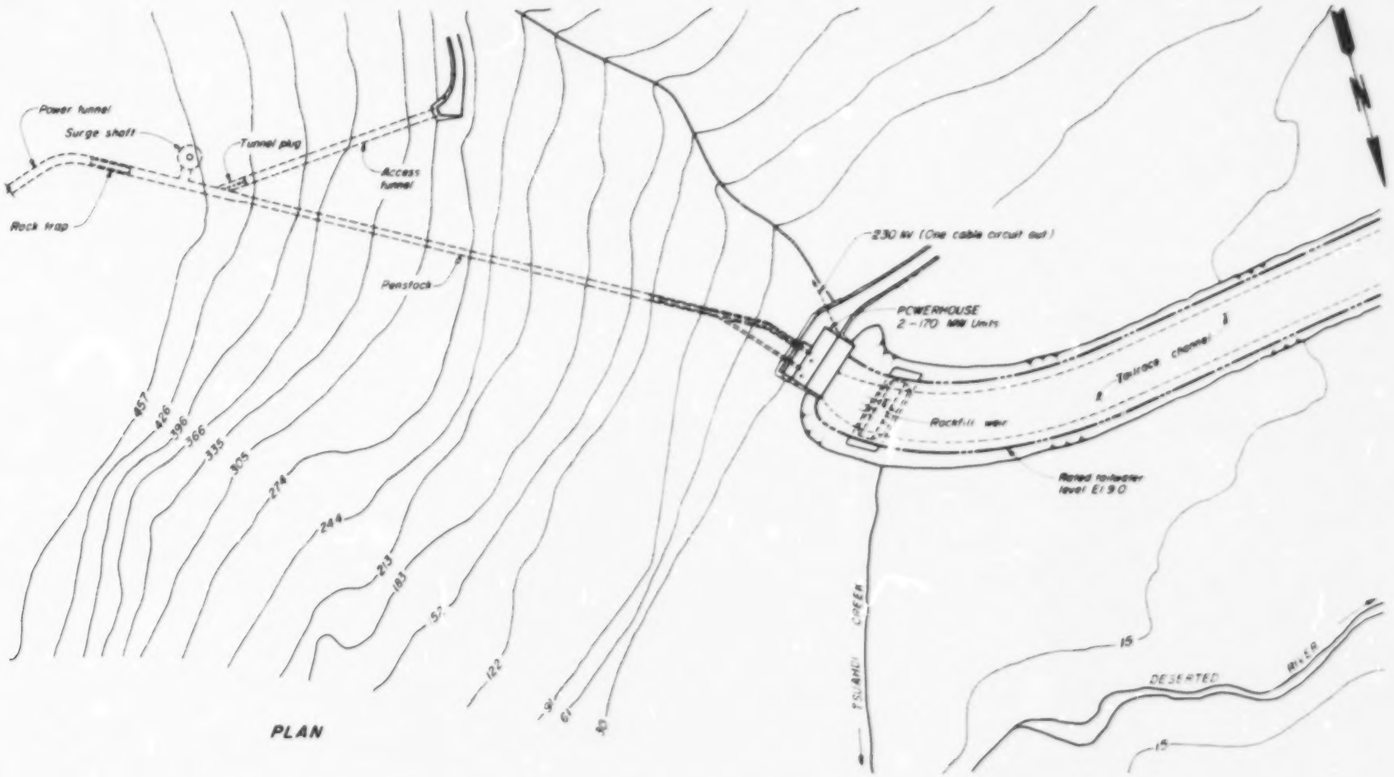
PLAN


Original rock surface
Power intake
Normal max reservoir level El. 360.0
Min reservoir level El 332.0
7.7m Dia D-shape power tunnel, 85% of length unlined - 15% shotcrete lined



SECTION THROUGH INTAKE, TUNNEL, PENSTOCK & POWERHOUSE

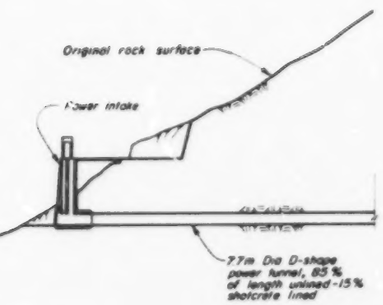


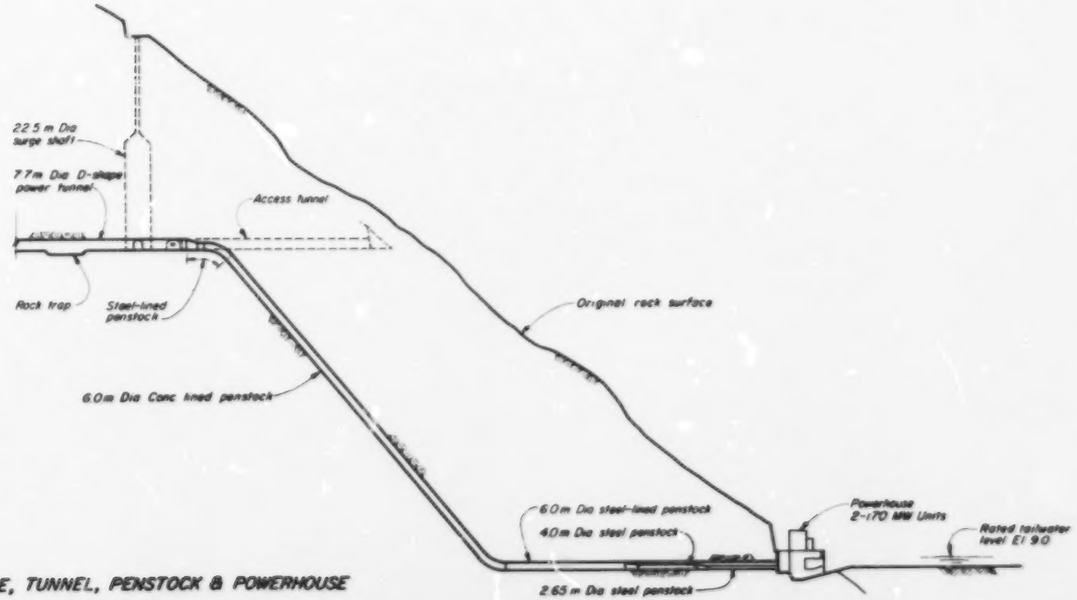


PLAN

ITEM	CALENDAR YEARS TO IN-SERVICE FROM AWARD OF FIRST CONTRACT					
	1	2	3	4	5	6
MOBILIZATION						
ACCESS						
CLEARING				TUNNEL CLOSURE		
DIVERSION TUNNEL		BEGIN DIVERSION				
COFFERDAMS						
MAIN DAM						
SPILLWAY						
POWER INTAKE						
POWER TUNNEL						
SURGE SHAFT						
PENSTOCKS						
POWERPLANT						
TAILRACE						

CONSTRUCTION SCHEDULE





SECTION THROUGH INTAKE, TUNNEL, PENSTOCK & POWERHOUSE

Scale 50 0 50 100 150 200 Metres

All dimensions are in metres, unless otherwise shown

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

DESERTED BAY POWER FACILITIES

PLAN AND PROFILE

GENERAL ARRANGEMENT -SHEET 1

DATE SEP 1983	FIG. 7-4
DWN GCB	DWG No 447-C14-U7

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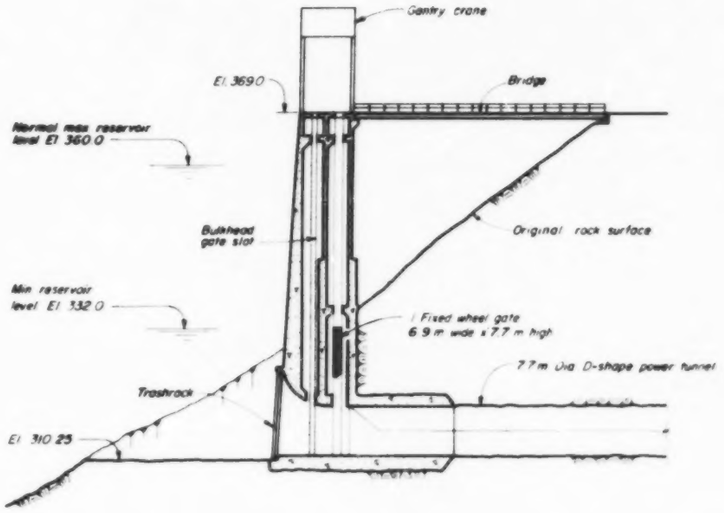
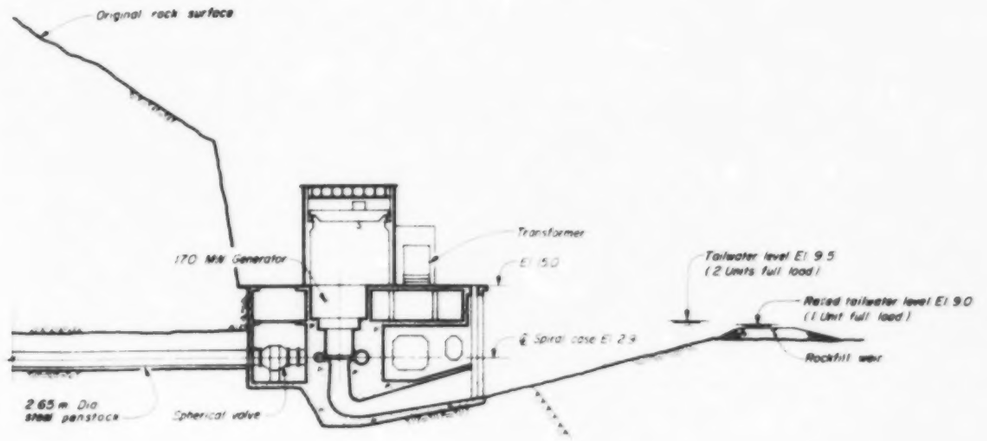
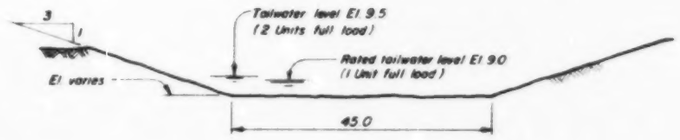


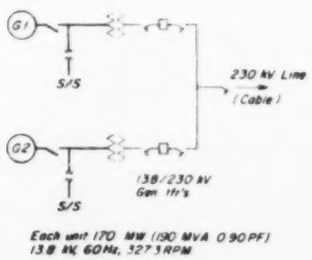
SECTION THROUGH POWER INTAKE


Original rock surface
Transformer
170 MW Generator
El. 15.0
Tailwater level El. 9.5 (2 Units full load)
Rated tailwater level El. 9.0 (1 Unit full load)
℄ Spiral case El. 2.9
Rockfill weir
2.65 m Dia. steel penstock
Spherical valve

SECTION THROUGH POWERHOUSE



SECTION THROUGH TAILRACE CHANNEL



Each unit 170 MW (190 MVA 0.90 PF) 13.8 kV, 60 Hz, 327.3 RPM

SINGLE LINE DIAGRAM

Scale: 10 0 10 20 30 40 Metres

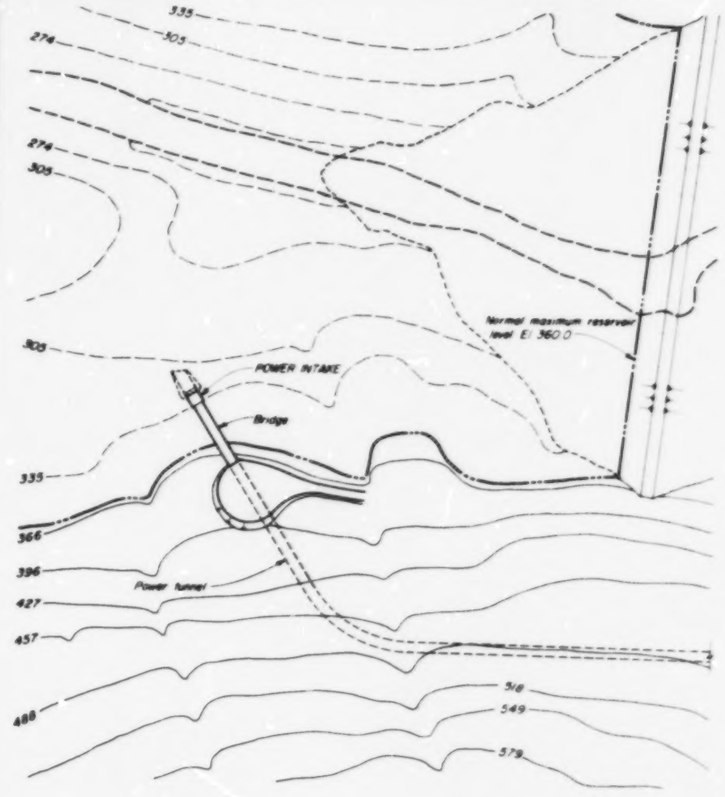
All dimensions are in metres, unless otherwise shown

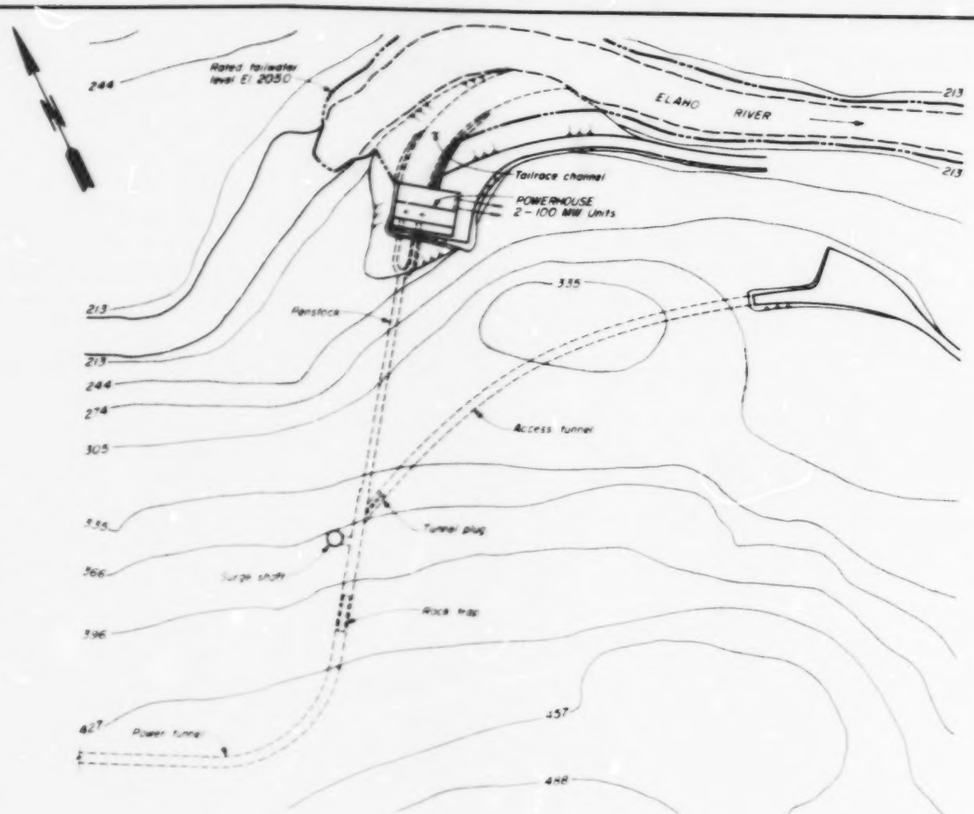
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

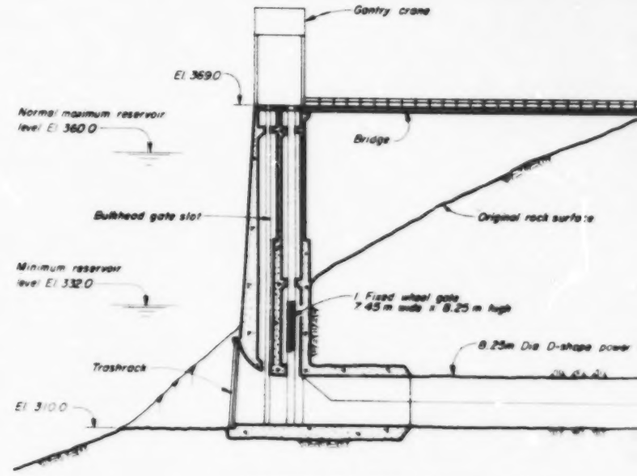
DESERTED BAY POWER FACILITIES SECTIONS GENERAL ARRANGEMENT - SHEET 2

DATE	FIG. 7-5
SEP 1983	
DWN GCB	447-C14-D8

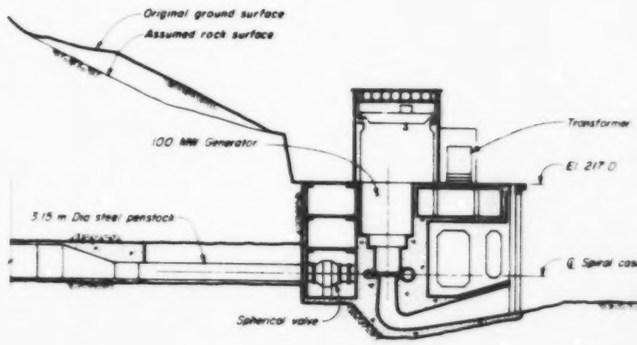




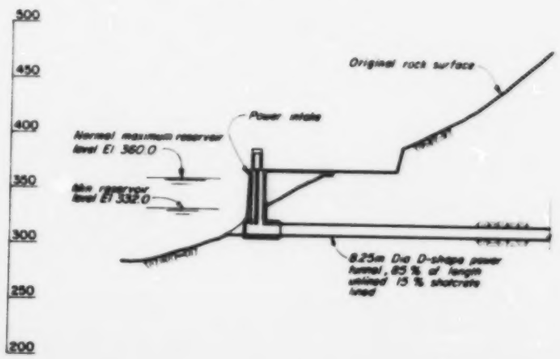
PLAN
Scale A

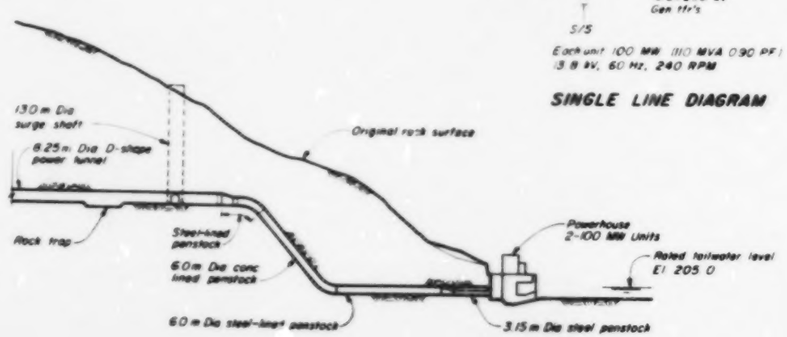


SECTION THROUGH POWER INTAKE
Scale B

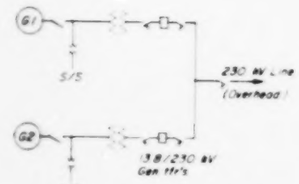


SECTION THROUGH POWERHOUSE
Scale B




13.0 m Dia surge shaft
8.25m Dia D-shape power tunnel
Original rock surface
Rock trap
Steel-lined penstock
6.0 m Dia conc lined penstock
Powerhouse 2-100 MW Units
Rated tailwater level El 205.0
6.0 m Dia steel-lined penstock
3.15 m Dia steel penstock

SECTION THROUGH INTAKE, TUNNEL, PENSTOCK & POWERHOUSE
Scale A



Each unit 100 MW (110 MVA 0.90 PF)
13.8 kV, 60 Hz, 240 RPM

SINGLE LINE DIAGRAM

ITEM	CALENDAR YEARS TO IN-SERVICE FROM AWARD OF FIRST CONTRACT					
	1	2	3	4	5	6
MOBILIZATION						
ACCESS						
CLEARING						
DIVERSION TUNNEL		BEGIN DIVERSION		TUNNEL CLOSURE		
COFFERDAMS						
MAIN DAM						
SPILLWAY						
POWER INTAKE						
POWER TUNNEL						
SURGE SHAFT						
PENSTOCKS						
POWERPLANT						
TAILRACE						

CONSTRUCTION SCHEDULE

Scale B 10 0 10

Scale A 50 0 50

All dimensions are in metres, unless

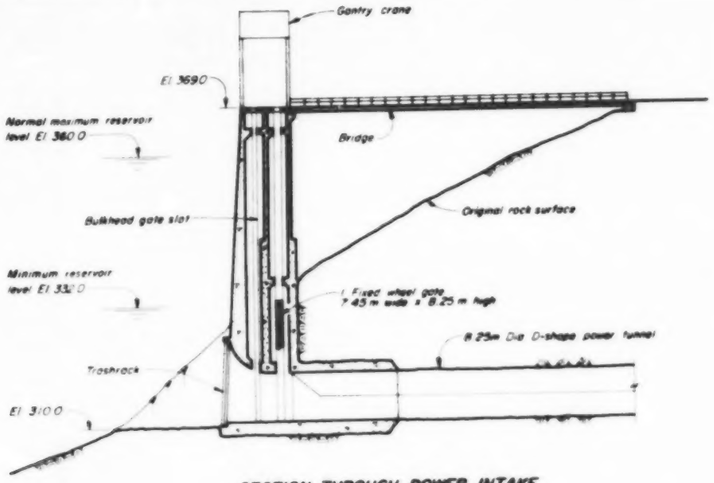
BRITISH COLUMBIA

ELAHO RIVER DEVELOPM
ELAHO RIVER PO
PLAN, PROFILE A
GENERAL ARRANG

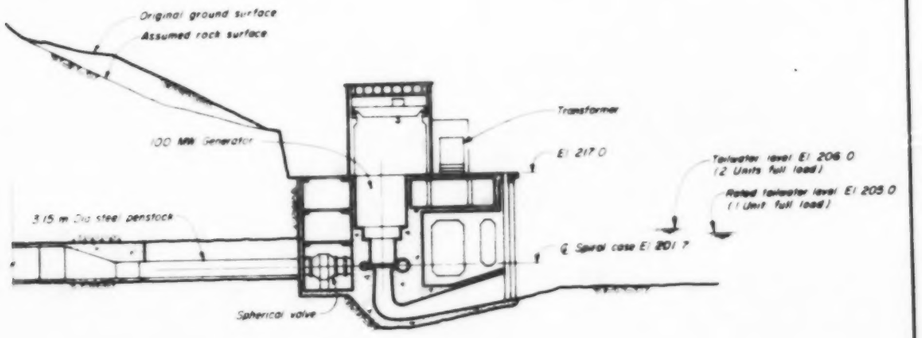
DATE SEP 1983

DWN GCB

REPORT No. H1595



SECTION THROUGH POWER INTAKE
Scale B


Original ground surface
Assumed rock surface
Transformer
100 MW Generator
El 217.0
Tailwater level El 206.0 (2 Units full load)
Rated tailwater level El 205.0 (1 Unit full load)
3.15 m Dia steel penstock
G Spiral case El 201.7
Spherical valve

SECTION THROUGH POWERHOUSE
Scale B

ITEM	CALENDAR YEARS TO IN-SERVICE FROM AWARD OF FIRST CONTRACT					
	1	2	3	4	5	6
RILIZATION						
ESS						
ARING				TUNNEL CLOSURE		
ERSION TUNNEL		BEGIN DIVERSION				
FERDAMS						
N DAM						
LLWAY						
WER INTAKE						
WER TUNNEL						
RGE SHAFT						
NSTOCKS						
WERPLANT						
LRACE						

CONSTRUCTION SCHEDULE

Scale B 10 0 10 20 30 40 Metres

Scale A 50 0 50 100 150 200 Metres

All dimensions are in metres, unless otherwise shown

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

ELAHO RIVER DEVELOPMENT OVERVIEW STUDY

ELAHO RIVER POWER FACILITIES PLAN, PROFILE AND SECTIONS GENERAL ARRANGEMENT

DATE	SEP 1983	FIG. 8-1
DWN	GCB	DWG No 447-C14-U9

REPORT No. H1595